Engineering Design

A Standards-Based High School Model Course Guide

Advancing Technological Literacy: ITEA Professional Series

Contemporary Curriculum for Technological Literacy

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Preface

Engineering Design is a course designed to foster problem-solving skills. One of the most significant labor shortages in the United States is that of technologically oriented people. Every year our government accepts more and more people from foreign countries on work visas to place them in technology-related fields. Although we are doing more than we have in the past to give our students opportunities to become technologically literate, too often educators place students in front of computers and assume that technological literacy follows.

Unfortunately, students in many schools can still graduate, having had no practical contact with engineering concepts or case studies. A major problem of secondary education is that schools teach science, technology, and mathematics only in the context of the specific disciplines. Learning to navigate the road to the solution is just as important, if not more important, than the solution itself. We need to teach the learning process that students require in order to navigate that road. Although all students may not become engineers, they do need problem-solving skills for life in the technologically complex twenty-first century.

Teachers should read and review the model course content and become familiar with all the units in this guide. It will be important to set time aside for advance planning before implementing this course. Perusing the listed Web sites and books, as well as finding additional resources, will be part of this planning time. The sample activities and academic connections in each unit are linked to technological literacy standards. Suggested learning activities in this guide may be adapted for your local setting. For example, if you live in a highly agricultural area, the class may focus more on agricultural and biotechnology activities. Or, if medical or communication technologies are prominent in your community, you may want to develop and use classroom activities that use local expertise and resources.

This guide presents content and activities in a cornerstone technology education model course for the high school. This guide is based on *Technology for All Americans: A Rationale and Structure for the Study of Technology* (*Rationale and Structure*) (ITEA, 1996) and *Standards for Technological Literacy: Content for the Study of Technology* (*Standards for Technological Literacy/STL*) (ITEA, 2000/2002). Further guidance is provided through *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards (AETL)* (ITEA, 2003). Because these ITEA publications contain the fundamentals of technological literacy curriculum, teachers, supervisors, and teacher educators are encouraged to review them prior to using this guide.

Technology for All Americans: A Rationale and Structure for the Study of Technology

Technology for All Americans: A Rationale and Structure for the Study of Technology provides a vision for the study of technology. It addresses the power and promise of technology and the need for every student to be technologically literate when he/she graduates from high school. Understanding the nature of technological advances and processes and participating in society's decisions on technological issues is of utmost concern. This publication outlines the knowledge, processes, and contexts for the study of technology.

Standards for Technological Literacy: Content for the Study of Technology

What is *Standards for Technological Literacy*?

ITEA, through its Technology for All Americans Project (TfAAP), published *Standards for Technological Literacy: Content for the Study of Technology (STL)* in April of 2000. *STL* defines, through K-12 content standards, what students should know and be able to do in order to be deemed technologically literate; however, it does not put forth a curriculum to achieve these outcomes. *STL* will help ensure that all students receive an effective education about technology by setting forth a consistent content for the study of technology.

Why is *STL* important?

- Technological literacy enables people to develop knowledge and abilities about human innovation in action.
- *STL* establishes requirements for technological literacy for all students from kindergarten through Grade 12.
- *STL* provides expectations of academic excellence for all students.
- Effective democracy depends on all citizens participating in the decision-making process; many decisions involve technological issues, so citizens need to be technologically literate.
- A technologically literate population can help our nation maintain and sustain economic progress.

Guiding Principles for *STL*

The *STL* standards and benchmarks were created with the following guiding principles:

- They offer a common set of expectations for what students should learn about technology.
- They are developmentally appropriate for students.
- They provide a basis for developing meaningful, relevant, and articulated curricula at the local, state, and provincial levels.
- They promote content connections with other fields of study in Grades K-12.
- They encourage active and experiential learning.

Who is a technologically literate person?

A person who understands—with increasing sophistication—what technology is, how it is created, how it shapes society, and in turn, how technology is shaped by society, is technologically literate. A technologically literate person can hear a story about technology on television or read it in the newspaper and evaluate its information intelligently, put that information in context, and form an opinion based on it. A technologically literate person is comfortable with and objective about the use of technology—neither scared of it nor infatuated with it.

Technological literacy is important to all students in order for them to understand why technology and its use is such an important force in our economy. Anyone can benefit by being familiar with it. All people, from corporate executives to teachers to farmers to homemakers, will be able to perform their jobs better if they are technologically literate. Technological literacy benefits students who will choose technological careers—future engineers, aspiring architects, and students from many other fields. Students have a head start on their future with an education in technology.

What is included in *STL*?

There are 20 content standards that specify what every student should know and be able to do in order to be technologically literate. The benchmarks that follow each of the broadly stated standards at each grade level articulate the knowledge and abilities that will enable students to meet the respective standard. A summary of the content standards is presented in Appendix B of this document. Teachers are encouraged to obtain *STL* to review the benchmarks associated with each standard.

Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards

While the *Rationale and Structure for the Study of Technology* provides a vision, and *Standards for Technological Literacy: Content for the Study of Technology* provides the content, neither was designed to address other important elements that are critical to a comprehensive program of technological studies. As a result, ITEA's Technology for All Americans Project published *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards (AETL)* in 2003. This publication will help schools to implement new strategies and evaluate existing practices of assessing students for technological literacy, providing professional development for teachers and other professionals, and improving programs of teaching and learning.

Advancing Technological Literacy: ITEA Professional Series

The Advancing Technological Literacy: ITEA Professional Series is a set of publications developed by the International Technology Education Association (ITEA) based on *Standards for Technological Literacy* (ITEA, 2000/2002) and *Advancing Excellence in Technological Literacy* (ITEA, 2003). The publications in this series are designed to assist educators in developing contemporary, standards-based K-12 technology education programs. This exclusive series features:

- Direct alignment with technological literacy standards, benchmarks, and guidelines.
- Connections with other school subjects.
- Contemporary methods and student activities.
- Guidance for developing exemplary programs that foster technological literacy.

Titles in the series include:

Technological Literacy Standards Series

- *Standards for Technological Literacy: Content for the Study of Technology*
- *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards*
- *Technology for All Americans: A Rationale and Structure for the Study of Technology*

Addenda to Technological Literacy Standards Series

- *Realizing Excellence: Structuring Technology Programs*
- *Developing Professionals: Preparing Technology Teachers*
- *Planning Learning: Developing Technology Curricula*
- *Measuring Progress: A Guide to Assessing Students for Technological Literacy*

Engineering by Design: Standards-Based Program Series

Elementary School Resources

- *Technology Starters: A Standards-Based Guide*
- *Models for Introducing Technology: A Standards-Based Guide*

Middle School Resources

- *Teaching Technology: Middle School, Strategies for Standards-Based Instruction*
- *Exploring Technology: A Standards-Based Middle School Model Course Guide*
- *Invention and Innovation: A Standards-Based Middle School Model Course Guide*
- *Technological Systems: A Standards-Based Middle School Model Course Guide*

High School Resources

- *Teaching Technology: High School, Strategies for Standards-Based Instruction*
- *Foundations of Technology: A Standards-Based High School Model Course Guide*
- *Engineering Design: A Standards-Based High School Model Course Guide*
- *Impacts of Technology: A Standards-Based High School Model Course Guide*
- *Technological Issues: A Standards-Based High School Model Course Guide*

Engineering by Design: Standards-Based Technological Study Lessons

Elementary School Resources

- Kids Inventing Technology Series (KITS)

Elementary/Middle School Resources (Grades 5-6)

- Invention, Innovation, and Inquiry (I^3) Lessons

- *Invention: The Invention Crusade*
- *Innovation: Inches, Feet, and Hands*
- *Communication: Communicating School Spirit*
- *Manufacturing: The Fudgeville Crisis*
- *Transportation: Across the United States*
- *Construction: Beaming Support*
- *Power and Energy: The Whispers of Willing Wind*
- *Design: Toying with Technology*
- *Inquiry: The Ultimate School Bag*
- *Technological Systems: Creating Mechanical Toys*

Secondary School Resources

- Humans Innovating Technology Series (HITS)

ITEA-CATTS

The International Technology Education Association-Center to Advance the Teaching of Technology and Science (ITEA-CATTS) was created in July 1998 to provide curriculum and professional development support for technology teachers and other professionals interested in technological literacy. ITEA-CATTS initiatives are directed toward four important goals:

- Development of standards-based curricula.
- Teacher enhancement.
- Research on teaching and learning.
- Curriculum implementation and diffusion.

The Center addresses these goals to fulfill its mission to serve as a central source for quality professional development support for the teaching and learning of technology and science. Teachers, local, state, or provincial supervisors, and teacher educators are encouraged to become familiar with ITEA-CATTS and how this Center will provide additional support as *STL* is implemented.

The ITEA-CATTS Consortium was established as part of ITEA-CATTS to form professional alliances in order to enhance teaching and learning about technology and science. Consortium members receive quality curriculum products and professional development based on the standards. This publication was conceptualized and developed through the Consortium.

Using This Guide

This guide provides standards-based content, activities, and resources for teaching a cornerstone technology course at the high school level. The information contained in this guide will assist teachers in preparing to implement *STL*. In addition, it can be used by state, provincial, and local curriculum developers in creating standards-based curriculum.

Chapter 1 addresses the high school learner and scope of a standards-based high school curriculum, an overview of methods described in this guide, and appropriate strategies for assessing students.

Chapter 2 features the units of instruction for this course. Each unit presents standards-based content for students in Grades 9-12. The unit framework consists of an overview, enduring results, teacher preparation, unit content, suggested learning activities, assessment, and resources.

Chapter 3 contains descriptions of resources, materials, and references that teachers may obtain as they develop curriculum and instructional materials. Teachers, curriculum developers, and other interested readers are encouraged to review the guide in its entirety. The content across the chapters and instructional units collectively contributes to quality instruction that addresses the standards.

Chapter 1

Scope and Sequence

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Introduction

High school is a period of preparation and application. Technology education at the high school level prepares students to use, manage, evaluate, and understand technology from a broad perspective in order to be technologically literate. This course guide reflects essential knowledge and activities that students should experience in a standards-based technology education class. This chapter will describe important instructional considerations for teaching high school students about technology. In addition, it will highlight instructional methods that go beyond traditional lecture, demonstration, and testing to allow students the opportunity to perform at higher levels and grow in their technological literacy. More detailed information on instructional methods for standards-based high school technology education courses can be found in *Teaching Technology: High School* (ITEA, 2000).

High School Curriculum Scope

Compared with the middle school student, the high school student has the opportunity to study technology in more detail and with more sophistication. At this level, students will engage in a wide range of instructional activities designed to build a detailed understanding of technology. Students who enter high school without prior learning in technological studies will need an orientation and introduction to the general concepts of technology and its study. The curriculum and instruction in eleventh and twelfth grades generally provide more depth in terms of content and laboratory-classroom experiences.

The breadth of the curriculum, beginning at the ninth grade level, is a matter of articulation between the middle school curriculum and the high school curriculum. Much effort should focus on the school system's ability to document students' achievement of technological literacy standards throughout their school years. Such information is critical to the development of curriculum and instruction at the high school level. An introductory high school course for all students should be offered to help high school students learn about fundamental technological concepts. "Foundations of Technology" is recommended as this cornerstone course in the high school technology education curriculum. (See *A Guide to Develop Standards-Based Curriculum for K-12 Technology Education*, ITEA, 1999).

Engineering Design prepares students to understand and apply engineering concepts and processes. Group and individual activities engage students in creating ideas, developing innovations, and engineering practical solutions. Technology content, resources, and laboratory/classroom activities encourage student applications of science, mathematics, and other school subjects in authentic situations. This course can be offered to students in Grades 9 through 12 and to students with diverse abilities. ***This course can be offered as a half-year or full-year course. Students enrolled in a single semester course (half-year) will attain fewer of the standards specified than students who take two semesters of Engineering Design.*

In order for students to fully attain the technological literacy standards, the following high school courses are also recommended:

- *Impacts of Technology*
  Technology has positive and negative impacts, and intended and unintended results. In this course, students learn ways to evaluate the appropriateness and effectiveness of various technologies. Students engage in technology activities to determine and evaluate the effectiveness of new ideas, innovations, and technological systems. Analytical thinking, decision making, and continuous design improvements are emphasized.

- *Technological Issues*
  Students investigate critical historical and emerging issues affecting the creation, development, use, and control of technology. Case studies, simulations, portfolio developments, and group seminars are ways that students address complex issues and propose alternative solutions to technological developments. Global governmental, social, and

economic policies concerning technology are studied.

- *Foundations of Technology* Designed as the cornerstone technology education course for the high school, it provides content and experiences that address the nature of technology, technology and society, relationships of technology with other content areas, and design concepts, approaches, and requirements. Different technologies provide exciting contexts as well as content that connects with the real world of technology. "Foundations of Technology" engages high school students in a broad study of technology and how it affects every aspect of our lives. In this course, students address crucial issues, current and future problems, and exciting opportunities associated with technology. In laboratory-classroom activities, they experience ways to create, use, improve, control, and evaluate technology that contribute to their technological literacy.

Instructional Methods

Design is one method that is implemented in this "Engineering Design" model course. A wide range of people conduct design activities throughout the course of any given day. Teachers frequently design instructional activities based on the learning objectives their students are expected to achieve. Engineers design new products, processes, and solutions based on a design's requirements. They apply mathematics and scientific principles to the development of a design. Frequently, they will use mathematical and computer models that inform the development process and predict the behavior of what is being created. Like most designers, engineers use iteration in the design process when they add an element to a design and then check the results against the requirements. Although the design processes used in various fields may be similar, a particular field may have unique standards and practices. For example, when production engineers design production tooling, they will apply a set of tooling design principles.

Technological problem solving is a method of instruction that provides students the opportunity to apply, analyze, synthesize, and evaluate what was learned from previous experiences. Using this method allows students the opportunity to *discover* new knowledge, develop critical-thinking skills, and manage their own learning. Additionally, it is a practical method for teaching very abstract concepts from other disciplines—science and mathematics, for example. Technological problem solving could include opportunities for discovery, research and development, and the use of engineering design briefs. These methods should be planned to consciously address technological literacy standards. While a comprehensive system of teaching technological problem solving is useful in any technological studies course, such a practice will prove especially important in "Engineering Design."

One model for technological problem solving proceeds in three phases: the design phase, the construction phase, and the evaluation phase (LaPorte & Sanders, 1996). If teachers use this basic procedure when their students are *engineering* various technological solutions to problems, they may provide continuity for students across the problem solving that they will attempt throughout the school year. Detailed information for using the technological problem-solving method can be found in *Teaching Technology: High School* (ITEA, 2001).

Discovery is the process of identifying new knowledge, insights, and realizations in the context of active modes of inquiry. An example of a discovery approach is when students apply the scientific method to discover something (learn something new) about the world. When students do, in fact, have the freedom to explore learning beyond the explicitly taught content, they will learn (with some guidance and structure) additional concepts and skills. But students have to be active to accomplish this. Their teacher needs to allow them to "think outside the box." Discovery is a major recommended outcome for technological studies.

Research and development (R and D) provides a means for investigating technological content using the process of inquiry. R and D is a recommended instructional method for high school students because they have the maturity and depth of knowledge in order to pursue specific areas of study related to the interests they have developed throughout their education. Research and development may be conducted in cooperative groups or as independent studies for individual students. For more information, see *Teaching Technology: High School* (ITEA, 2001).

Design briefs can be used to introduce or frame a problem. While design briefs may be highly structured and specific when they are used with a new class of students, they may provide less structure as students become more sophisticated. Students may even write their own design briefs. A difficult-to-machine product in a manufacturing production run is an example of a very specific problem with a narrow scope. While there may be more than one correct solution to the problem, the exercise provides an example of a teaching method for a specific type of content. On the other hand, an example of a broad problem might involve the lack of adequate housing in a community, and solving it may require the application of broad content. These methods are described in detail in *Teaching Technology: High School* (ITEA, 2001) and *Measuring Progress: A Guide for Assessing Students for Technological Literacy* (ITEA, 2004). The teacher is encouraged to review *Measuring Progress* in preparation for implementing "Foundations of Technology."

Assessing Students

Assessing students involves continuously monitoring student progress toward understanding technology content and developing abilities for a technological world. This guide provides guidance for assessing students in the unit sections labeled acceptable evidence and in each assessment section following the suggested learning activities. Assessing students using multiple approaches during and following teaching and learning activities is strongly encouraged. The following assessment approaches may be used to monitor student progress and achievements:

- Performance assessment is perhaps the most authentic assessment method next to on-the-job performance and ultimately prospering as a citizen. Because students need to learn design concepts, they should participate in designing real-life products, processes, and solutions. By watching students use a given technology, teachers can determine their proficiency at using and controlling it. This performance assessment method allows teachers to get around typical problems associated with written testing—validity and reliability, for example. Performance can be measured during an activity that is set in a real-life context or in a formal setting. It can also be used to measure all levels of learning in all three domains of learning discussed in Chapter 1. Performance measures should initially center on content (processes and products) specified in the standards and their related benchmarks.

- Using rubric assessments will provide teachers with an inventory of desired behaviors and guide them in making judgments regarding student achievement within a range of mastery. After developing the objectives and activities for a unit, teachers should develop a listing of desired behaviors. The behaviors should be derived from the objectives, considering the context of the activity and using the objective criteria (Custer, 1996). Teachers should develop rubrics to use when judging or scoring students' portfolios. Some considerations for developing criteria for portfolio judging or scoring are outlined in *Teaching Technology: High School* (ITEA, 2001).

- Self-assessment provides an alternative to written tests. Teachers should encourage students to reflect on their own performance. For student self-assessment, teachers should ask individual students to compare perceptions of their own work to the guidelines and criteria that have been established. These criteria are those same elements that are identified by students as requirements. This process provides the teacher with an opportunity to "get inside" the student's mind to assess things like creativity and metacognition. Self-assessment can be made a regular part of the student's portfolio, and teachers can include a checklist component or rubric, as well as a written narrative component.

- Group and peer assessments are a valuable measure of student learning within groups. Students will frequently work in groups and may be afforded the opportunity to assess the achievement of their own groups. The criteria would focus on group dynamics, responsibility, organization, strategies, and presentations.

- Physical Products/Projects Teachers should develop rubrics or checklists to judge or score student projects. The criteria for the rubric or checklist may be determined, in part, by students when they set criteria for developing a solution to a design problem or challenge.

- Student lab reports/journals Scientists and engineers are required to keep extensive notes on their daily progress on projects not only to inform their employers but to prove that the ideas were actually their own. Instructors should use the lab report as a tool to keep track of individual student progress. This practice links English writing skills with technology. The journal or lab report is also an important document when discussing a student's progress with parents. Lab reports or journals can cover one or two week's worth of work at a time, and should be kept in the classroom (Gomez, 2001).

- Essays are used to assess student understanding through synthesis, analysis, and evaluation of broad concepts and issues. Teachers should set up a structure or rubric for grading the essay assignment. Internet sites and electronic information can open up problems when it comes to essays, such as plagiarism. Teachers should precede the essay assignment with an explanation of the school's policy on plagiarism and the specified consequences. One way to see if students truly researched a topic or simply cut and pasted electronic information is to include a brief essay on the final exam synthesizing the student's previous essay assignments (Gomez, 2001).

- Portfolio development is recommended in several unit activities. Portfolios are not journal notebooks in which students write every thought or note. Student portfolios do not necessarily have to be as clean and pleasing as a portfolio a designer would use to show his or her best work. Student portfolios may be a combination of a design portfolio and a means of communicating achievement, growth, and insights to the teacher, parents, and even future colleges and employers. The portfolio reflects student thinking and visualizing processes as well as design stages in the products and systems they produced in technology class.

- Formative assessments
  Multiple-choice and short-answer tests may be appropriate ways to check understanding of content. Formative assessments may be used in conjunction with the above assessment strategies to assess understanding of core concepts and principles.

- Student interviews by the teacher can be conducted to assess level of understanding and to probe for feasible solutions to design problems. Teachers may develop sample questions in advance of an activity to guide the interviews. Student-generated questions may be used to assess progress.

- Seminars and panel discussions provide opportunities for formal and informal assessments in which students share their knowledge and understandings and give everyone else a feel for the progress of the group as a whole. Teachers assess student knowledge and presentation of knowledge using these strategies.

Regardless of the assessment strategies selected, the teacher should use a variety of assessments to ensure that students are learning the specified content in each of the units.

Unit Framework

Each unit is organized according to the following sections to prepare the teacher to successfully implement the unit content.

Standards Addressed
Standards-based curriculum begins with technological literacy standards. The standards in *Standards for Technological Literacy: Content for the Study of Technology (STL)* (ITEA, 2000/2002) emphasize what every student should know and be able to do in order to be technologically literate. This section outlines which *STL* standards will be addressed in the unit.

Big idea indicates the concepts that will be retained over time and activities that the students will be able to do upon completion of the unit.

Student Assessment Criteria
Assessment criteria are indicators that suggest the level of understanding attained by students. Assessment criteria provide the basis for teaching and learning by capturing the essential ingredients of the content being measured. They are written to provide cues to teachers and their students about what significantly indicates student technological literacy.

Student Learning Experiences indicate big ideas that are related to selected content standards and benchmarks from *Standards for Technological Literacy: Content for the Study of Technology* (*STL*), (ITEA, 2000/2002). These specify outcomes that students should know and be able to do as related to the study of technology.

Acceptable Evidence identifies what students will need to do to demonstrate that they have attained the specified standards. Using more than one assessment approach for a standard provides a more complete picture of each student's knowledge and abilities.

Overview introduces the technology content for the unit and suggests ways for the teacher to begin the unit instruction.

Teacher preparation provides guidance to the teacher for gathering information, consulting with content specialists, and preparing for the suggested instructional activities.

Unit Content is based on the enduring results at the beginning of the unit. The content is presented in outline form and provides a suggested sequence for the unit.

Suggested Learning Activities present activities that teachers can use to support the content in the unit. The teacher may decide to use other instructionally appropriate activities that contribute to the enduring results.

Assessment is key to monitoring student progress and ensuring that students understand the content. This section suggests ways to assess individuals and groups of students.

Resources related to the unit content and activities are given for teacher reference. Resources include books, videos, and Web sites. Note: Web site information may change. Care has been taken to identify stable sites.

In Chapter 2, the following units of instruction will be presented:

- Unit 1 will introduce students to Systems and Optimization. The application of logic and creativity, with compromises and the interaction of humans and technological systems, will be investigated.

- In Unit 2, students will be introduced to the effects and influences of technology as well as ethics. This unit will explore the cultural, social, economic, and political effects of technology, and the effects of technology on the environment. Within the ethics portion of this unit, students will participate in discussions and debates on ethical issues in an open forum with a pass/fail grading scheme.

- In Unit 3, students will be introduced to concurrent engineering and teamwork. Teamwork and concurrent engineering are key tools in a successful experience in engineering.

- In Unit 4, students will be introduced to problem solving and modeling.

- In Unit 5, students will be introduced to the attributes of design. Students will be able to apply the design process. Students will design, build, and test prototypes for different problems.

Each unit will provide suggestions for content, methods, and assessment strategies. Technology teachers can use this information to develop and implement instruction that develops technological literacy in their students.

End-of-Course Assessment Rubric – Engineering Design

<table>
<tr><th>Achievement Level / Sub-concept</th><th>Above Target
3</th><th>At Target
2</th><th>Below Target
1</th></tr>
<tr><td>Concepts of Technology
• Systems
• Processes
• Resources
• Impacts</td><td>• Thoughtfully designs, prototypes, and tests a technological <u>system</u> that effectively accomplishes an outcome and includes input, process, output, and feedback components.
• Correctly, safely, and efficiently operates and maintains effective technological systems that <u>process</u> matter and data.
• Effectively, efficiently, and appropriately applies <u>resources</u> to a task, with highly positive results.
• Insightfully and critically assesses and makes thoughtful recommendations about the <u>impacts</u> of the systems and processes employed and the appropriate use of resources with respect for individuals, society, and the environment.</td><td>• Designs, prototypes, and tests a technological <u>system</u> that accomplishes an outcome and includes input, process, output, and feedback components.
• Operates and maintains effective technological systems that <u>process</u> matter and data.
• Adequately applies resources to a task with positive results.
• Assesses and makes recommendations about the <u>impacts</u> of the systems and processes employed and the appropriate use of resources with respect for individuals, society, and the environment.</td><td>• Designs, prototypes, and tests a technological <u>system</u> that accomplishes an outcome and includes input, process, output, and feedback components, but may not accomplish the system's objectives.
• Operates and maintains, with minimal effectiveness, technological systems that <u>process</u> matter and data.
• Ineffectively applies <u>resources</u> to a task with minimally positive results.
• Reviews the <u>impacts</u> of the systems and processes employed and the appropriate use of resources with respect for individuals, society, and the environment.</td></tr>
<tr><td>Technology and Society
• Change
• Balance
• Impacts
• Issues</td><td>• Insightfully compares technological <u>change</u>, how humans influence technological development, and how individuals and society adjust to change.
• Thoroughly assesses the <u>balance</u> of cost/benefits and trade-offs of different technological activities.
• Thoughtfully analyzes the <u>impacts</u> and extent to which a technological activity has accomplished its objectives, created new challenges, and generated new knowledge.
• Critically assesses the value of applying a technology and whether a given new technology should or should not be developed.</td><td>• Compares technological <u>change</u>, how humans influence technological development, and how individuals and society adjust to change.
• Assesses the <u>balance</u> of cost/benefits and trade-offs of different technological activities.
• Analyzes the <u>impacts</u> and extent to which a technological activity has accomplished its objectives, created new challenges, and generated new knowledge.
• Assesses the value of applying a technology and whether a given new technology should or should not be developed.</td><td>• Compares, to a limited extent, technological <u>change</u>, how humans influence technological development, and how individuals and society adjust to change.
• Assesses, to a limited extent, the <u>balance</u> of cost/benefits and trade-offs of different technological activities.
• Analyzes, but with little depth, the <u>impacts</u> and extent to which a technological activity has accomplished its objectives, created new challenges, and generated new knowledge.
• Assesses, but with little substantiation, the value of applying a technology and whether a given new technology should or should not be developed.</td></tr>
<tr><td>Concurrent Engineering
• Design Process
• Teamwork
• Organization & Schedule Management
• Productivity</td><td>• Thoroughly analyzes a problem or opportunity situation, explores possibilities, proposes solutions and <u>designs</u>, tests models, prototypes a likely solution, and proposes the best answer.
• Effectively coordinates the efforts of <u>a design team</u> to systematically address a problem or opportunity situation.
• Effectively coordinates the efforts of <u>several design teams</u> to insure that all elements of a project are coming together on a timely, efficient, and effective schedule.
• Analytically and thoughtfully assesses the effectiveness of a design through <u>production</u> processes of a project to determine the extent to which all elements came together efficiently.</td><td>• Analyzes a problem or opportunity situation, explores possibilities, proposes solutions and <u>designs</u>, tests models, prototypes a likely solution, and proposes the best answer.
• Contributes effectively as a team member to the efforts of <u>a design team</u> to systematically address a problem or opportunity situation.
• Effectively participates in the efforts of <u>several design teams</u> to insure that all elements of a project are coming together on a timely, efficient, and effective schedule.
• Assesses the effectiveness of a design through <u>production</u> processes of a project to determine the extent to which all elements came together efficiently.</td><td>• Analyzes, but with minimal insight, a problem or opportunity situation, explores possibilities, proposes solutions and <u>designs</u>, tests models, prototypes a likely solution, and proposes the best answer.
• Functions ineffectively as a team member in the efforts of <u>a design team</u> to systematically address a problem or opportunity situation.
• Participates as a member of one of <u>several design teams</u> to help insure that all elements of a project are coming together on a timely, efficient, and effective schedule.
• Assesses, but with some difficulty, the effectiveness of a design through <u>production</u> processes of a project to determine the extent to which all elements came together efficiently.</td></tr>
</table>

End of Course Assessment Rubric – Engineering Design, continued

Achievement Level / Sub-concept	Above Target 3	At Target 2	Below Target 1
Modeling • Thinking Processes • Types of Models • Communica-tion Process	• **Conceptualizes** the breadth and depth of a project; **creatively visualizes** the possibilities and potential problems; applies **various** idea-generating processes, including modeling; gathers data, tests solutions, and **effectively presents** plausible answers. • **Makes creative and extensive use of** sketches, drawings, and scenarios **along with** computer, mathematical, and physical models to generate and test **a variety** of ideas. • **Creatively and effectively conceptualizes and presents** ideas using **a variety** of presenta-tion media and techniques, including models.	• **Sees, with some understand-ing,** the breadth and depth of a project; **visualizes some** possibilities and potential problems; applies **several** idea-generating processes, including modeling; gathers data, tests solutions, and **presents** plausible answers. • **Uses** sketches, drawings, and scenarios **along with** computer, mathematical, and physical models to generate and test **a variety** of ideas. • **Effectively conceptualizes and presents** ideas using **a variety** of presentation media and techniques, including models.	• **Sees, but with little under-standing,** the breadth and depth of a project; **focuses on a** possibility with **little** consideration for potential problems; applies **a few** idea-generating processes, including modeling; gathers **little** data; tests solutions and **pre-sents** plausible answers **with minimal effectiveness**. • **Makes little use of** sketches, drawings, and scenarios **along with** computer, mathematical, and physical models to generate and test **a variety** of ideas. **Tends to lock in on the first idea without exploring other possibilities.** • **Presents ideas with some degree of effectiveness,** using **a limited amount** of presentation media and techniques with **little use** of models.
Problem Solving • Defining the Challenge • Proposing Solutions • Testing Possibilities • Applying the Design	• The challenge is **very clear, specific, and focused.** • Sketches, drawings, and descriptions suggest a **wide range of possibilities**. • **Effective** drawings, descriptions, and prototypes of several possibilities. • An **effective** drawing, model, portfolio, and presentation of a creative solution.	• The challenge is **very clear, specific, and focused.** • Sketches, drawings, and descriptions suggest a **wide range of possibilities**. • **Effective** drawings, descriptions, and prototypes of several possibilities. • An **effective** drawing, model, portfolio, and presentation of a creative solution.	• The challenge is **not sufficiently clear, specific, and focused.** • Sketches, drawings, and descriptions suggest a **narrow range of possibilities**. • **Effective** drawings, descriptions, and prototypes of few possibili-ties. • A drawing, model, portfolio, and presentation of a solution.
Design ▪ Envisioning Opportuni-ties ▪ Ideation ▪ Testing the Design ▪ Presenting and Applying the Design	• **Creatively and with depth, appraises** the future, **thinks globally** and beyond, and takes into account the individual and collective needs and desires of the global community. • Generates a **wide range of creative ideas** using a **variety of techniques** and takes **all** possibilities into consideration. • **Creatively** sketches, draws, and describes ideas; develops computer, mathematical, and physical models; prototypes and tests promising design possibilities; **accurately** generates, analyzes, and draws conclusions from data. • **Creatively and convincingly** presents and demonstrates design ideas using **a variety** of presenta-tion media and techniques, including test data, models, and prototypes.	• **Appraises** the future, **thinks globally** and beyond, and takes into account the individual and collective needs and desires of the global community. • Generates a **range of ideas** using a **variety of techniques** and takes **several** possibilities into consideration. • Sketches, draws, and describes ideas; develops computer, mathematical, and physical models; prototypes and tests promising design possibilities; generates, analyzes, and draws conclusions from data. • Presents and demonstrates design ideas using **a variety** of presenta-tion media and techniques, including test data, models, and prototypes.	• **Appraises** the future, **thinks narrowly**, and **has difficulty** taking into account the individual and collective needs and desires of the global community. • Generates a **few ideas** using **several techniques** and takes **only a few** possibilities into consideration. • **With difficulty,** sketches, draws, and describes ideas; develops computer, mathematical, and physical models; prototypes and tests promising design possibili-ties; generates, analyzes, and draws conclusions from data. • Presents and demonstrates design ideas using presentation media and techniques.

Chapter 2

Units of Instruction

Chapter 2, Unit 1

Systems and Optimization

Standards for Technological Literacy Standards Addressed in Unit 1

Unit 1 addresses the following *STL* standards:

- **Standard 2** Students will develop an understanding of the core concepts of technology.
- **Standard 14** Students will develop an understanding of and be able to select and use medical technologies.

Big Ideas

Concepts of Technology and Medical Technology

Student Assessment Criteria – Concepts of Technology

Achievement Level / Sub-concept	Above Target 3	At Target 2	Below Target 1
Systems	**Thoughtfully designs**, prototypes, and tests a technological system that **effectively accomplishes** an outcome and includes input, process, output, and feedback components.	**Designs**, prototypes, and tests a technological system that **accomplishes** an outcome and includes input, process, output, and feedback components.	**Designs**, prototypes, and tests a technological system that includes input, process, output, and feedback components **but may not accomplish the system's objectives.**
Processes	**Correctly, safely, and efficiently operates and maintains effective** technological systems that process matter (separate, form, combine, and condition) and data (collect/ detect, manipulate, and display).	**Operates and maintains effective** technological systems that process matter (separate, form, combine, and condition) and data (collect/ detect, manipulate, and display).	**Operates and maintains with minimal effectiveness,** technological systems that process matter (separate, form, combine, and condition) and data (collect/ detect, manipulate, and display).
Resources	**Effectively, efficiently, and appropriately** applies resources (materials, energy, personnel, information, capital, and property) to a task, with **highly positive results**.	**Adequately** applies resources (materials, energy, personnel, information, capital, and property) to a task, with **positive results**.	**Ineffectively** applies resources (materials, energy, personnel, information, capital, and property) to a task, with **minimally positive** results.
Impacts	**Insightfully and critically assesses and makes thoughtful recommendations** about the impacts of the systems and processes employed and the appropriate use of resources, with respect for individuals, society, and the environment. **Probes** the extent to which the objectives of a technological activity were attained, new challenges and opportunities were created, and new knowledge was generated.	**Assesses and makes recommendations** about the impacts of the systems and processes employed and the appropriate use of resources, with respect for individuals, society, and the environment. **Questions** the extent to which the objectives of a technological activity were attained, new challenges and opportunities were created, and new knowledge was generated.	**Reviews** the impacts of the systems and processes employed and the appropriate use of resources, with respect for individuals, society, and the environment. **Asks few questions** about the extent to which the objectives of a technological activity were attained, new challenges and opportunities were created, and new knowledge was generated.

Student Assessment Criteria – Medical Technology

Achievement Level / Sub-concept	Above Target 3	At Target 2	Below Target 1
Prevention	**Thoroughly compares** the relationship between good health and the technology associated with factors such as exercise, nutrition, monitoring (check-ups), vaccines, genetic modifications, and heredity.	**Compares** the relationship between good health and the technology associated with factors such as exercise, nutrition, monitoring (check-ups), vaccines, genetic modifications, and heredity.	**Marginally compares** the relationship between good health and the technology associated with factors such as exercise, nutrition, monitoring (check-ups), vaccines, genetic modifications, and heredity.
Diagnosis	**Clearly explains** the technology used to diagnose health-related issues and **thoughtfully speculates** about how new technology could detect future problems before they become obvious.	**Explains** the technology used to diagnose health-related issues and **speculates** about how new technology could detect future problems before they become obvious.	**Explains to a limited extent** the technology used to diagnose health-related issues and **lists a few ways** about how new technology could detect future problems before they become obvious.
Treatment	**Explains in detail and with documentation**, how new technology has aided in treating medical problems, the impacts (positive and negative) those treatments have had, and areas where new technological developments and policy decisions could help to improve the quality of life globally.	**Explains in some detail and with a little documented support**, how new technology has aided in treating medical problems, the impacts (positive and negative) those treatments have had, and areas where new technological developments and policy decisions could help to improve the quality of life globally.	**Explains, but with limited documentation**, how new technology has aided in treating medical problems, the impacts (positive and negative) those treatments have had, and areas where new technological developments and policy decisions could help to improve the quality of life globally.
Rehabilitation	**Effectively explains, with supporting documentation**, how technology aids in a person's recovery from a treatment procedure or injury and how new technology might further enhance the recovery process.	**Explains** how technology aids in a person's recovery from a treatment procedure or injury and how new technology might further enhance the recovery process.	**Explains, with minimal effectiveness,** how technology aids in a person's recovery from a treatment procedure or injury and how new technology might further enhance the recovery process.

Student Learning Experiences

System Loops
Material Systems Dissection
Texas Traffic
Waste Management Systems
Stress Analysis

As a set of learning experiences, the following *STL* content standards and corresponding benchmarks are addressed: Standard 2, Benchmarks W, X, Y, Z, AA,BB, CC, DD, EE, and FF; Standard 14, Benchmarks K, L, and M. However, if you choose to use only a specific activity, please refer to Appendix B to determine exactly which standards and benchmarks are being addressed by that learning experience. See **Appendix B** for a complete listing of the *STL* content standards.

Acceptable Evidence of Student Understanding

1. Document daily progress in a lab report or journal.
2. Define and apply terms related to systems in the correct context
3. Analyze a system and subsystems and identify the input, process, output, and feedback loops.
4. Create a functioning system that incorporates input, process, output, and feedback loops.
5. Safely dissect a material system, breaking it down into specific material categories.
6. Assess a system, forecast the future of the technology, and predict where the system could be improved.
7. Analyze data provided by a system and give feedback for re-design.
8. Present research on the development of a waste management system. Create a model to inform others of the research and a solution to the problem.
9. Collect pulse rate data and organize it.
10. Analyze results of data collection and make a hypothesis.

Special note: Please keep in mind that criteria must be developed to measure the evidence that students provide in demonstrating their levels of understanding—what are we looking for and how will we know it when we see it? For example, if students are asked to build a model, how will we know if it's a good one?

When considering achievement levels and helping students to understand how they might improve, it will be necessary to know what we mean by terms such as effectively, efficiently, adequately, creatively, thoughtfully, mostly, clearly, minimally, marginally, correctly, safely, systematically, randomly, logically, thoroughly, introspectively, insightfully, and meaningfully. (See **Appendix D, Acceptable Evidence Glossary**, for definitions.)

Overview

A system is a means of achieving a desired result. It has input, process, output, and feedback. The system approach can also be considered a way of thinking. Whenever you are presented with a problem or a case study, simply break it down into smaller subsystems to simplify the approach. For example, an automobile has systems and subsystems: mechanical systems (gears and pulleys); electrical systems (battery, wiring, and now computers in new cars); and fluid systems. As the driver, you become the input part of the system when you feed the car information in the form of pressure on gas and brake pedals. You manipulate a wheel mounted to a column that controls the direction of the vehicle.

The automobile converts the input to process, obeying the driver's signals and converting them into output. Does the vehicle "want" to engage its four-wheel drive? Will the brakes "choose" to function correctly when the driver "miscalculates" and has to slam them only ten feet from a tree or another vehicle? If one of these systems fails, the driver certainly wants to have feedback. In a vehicle, the gauges and displays give one form of feedback—from the fuel gauge to the large warning lights that simply tell you that something is wrong with your engine. We do not think of these "feedbacks" consciously until a crisis arises, like looking down at the speedometer after passing a police vehicle.

Optimization can be defined as doing the most with the least. A crude but distinct example would be that of cutting a 2" by 2" square out of a piece of paper. Would cutting it out of the center be the best solution? Or might it be a better solution to use the edges of the paper in a corner to eliminate two unnecessary cuts and have a large portion of the paper uninterrupted for future use?

Most design problems we face have no definitive answer. Most solutions are a series of compromises, which, in turn, allow the product to function well. An engineer or technician must assess all the parts of a problem and optimize each before the job is resolved. Webster's Dictionary defines optimization as "The procedure or procedures used to make a system or design as effective or functional as possible, especially the mathematical techniques involved."

Teacher Preparation

The following general suggestions will help the teacher prepare for instruction in this unit. To begin, review the technological literacy standards and academic connections for this unit. You may want to meet with the math and science teachers in your school or school district to obtain input for the content in this unit and additional resources for the class. Another suggestion is to contact local businesses or engineering experts to get another perspective on the unit content and activities. Locate the resources recommended at the end of each case study and review their content.

You may want to introduce this unit by pointing out recent technology-related issues and events cited in the national or local newspaper. Prepare questions that will engage students in a discussion of the potential impacts of these issues locally and globally.

Unit 1 Content Outline

- I. Core concepts in technology
  - A. Systems
    - 1. Application of logic and creativity with compromises
    - 2. Systems can be embedded within other systems
    - 3. Stability of a system is related to its components
    - 4. Feedback loop may be the most important step
    - 5. Human systems
      - a. Family
      - b. Government
    - 6. Interaction between human and technological systems
  - B. Resources
    - 1. Availability
    - 2. Cost
    - 3. Desirability
    - 4. Waste
    - 5. Requirements
      - a. Criteria
      - b. Constraints
      - c. Effect on final design
  - C. Optimization and trade-offs
  - D. Processes/new technologies
    - 1. New technologies create new processes
    - 2. Can new processes create new technologies?
  - E. Controls
    - 1. Quality control
    - 2. Management
  - F. Complex systems
    - 1. Many layers of controls/feedback loops
    - 2. Provide information
- II. Medical Technologies
  - A. Prevention
  - B. Rehabilitation
  - C. Vaccines
  - D. Pharmaceuticals
  - E. Medical and surgical procedures
  - F. Genetic engineering
  - G. Telemedicine
    - 1. Medicine
    - 2. Telecommunications
    - 3. Virtual presence
    - 4. Computer engineering
    - 5. Informatics
    - 6. Artificial intelligence
    - 7. Robotics
    - 8. Materials science
    - 9. Perceptual psychology
  - H. Biochemistry
  - I. Molecular biology
    - 1. Manipulate the genetic materials

Suggested Learning Activities

These suggested activities support the content for this unit. The teacher may use alternate activities, but care should be taken to see that these activities reflect the specified content and address the *STL* content standards listed at the beginning of this Unit.

System Loops

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *3-5 days*

Teacher Preparation

This case study will take three to five classroom days to complete. Students will need to be familiar with the systems model presented in the beginning of this unit. Students will also need CAD skills or orthographic hand-drawing skills for this case study. This may add time to the case study to get students the skills needed to complete the drawings. Materials for the models can be of any type as long as they don't hinder the progress of the case study. For example, welding steel tubing may be a good way of representing a system, but since these are models, a foam core tube, glued to simulate the system, would be enough for representation.

Case Study

The philosophy of a bicycle has been around since 1817, when Baron von Drais invented a walking machine that helped him get around better. This wasn't pedal-powered; he simply walked alongside it and pushed it for power. In 1865 the first bicycle, known as the Velocipede or Boneshaker, used pedals to power it.

In the twenty-first century, you can now build your own bike online through Web sites like the one that TREK offers. Composite materials, special frames, and complicated aerodynamics are just a few of the systems involved in bikes today. The future of this industry holds many advancements and innovations that are designed into prototype bicycles every day. Many of these developments may become part of the bikes that show up in stores in the coming years.

In this case study, student teams of three will examine bicycles to determine what systems they have. The teams will also create input, process, output, and feedback loops for each system in order to explain it to the class. A presentation will be required on at least one of the systems of a bicycle. Teams will present detailed information to the class through electronic presentations, physical and graphical models of the specific system, and written text of the system. The instructor of the class will assign the team a specific system, and the following are the minimum requirements of the presentation:

1. Define the input, process, output, and feedback loops specifically.
2. Replicate the system to scale (to be determined by the team) with the use of mechanical

This CNC (Computer Numerical Control) Router has many different systems within it. How many can you name?

design software, or through orthographic hand drawings.

3. Replicate the teams' recommended modifications to the system to scale (to be determined by the team) with the use of mechanical design software, or through orthographic hand drawings. This can be an overlay for a hand drawing, a layer in a CAD drawing, or a pop-on part for a scale model.
4. Build a scale model of the system that is assigned to your team.
5. Write a report on the system, describing the specific uses, advantages, and disadvantages of the loops and what your team would design to improve the system.

Assessment

System Loops Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Definition of Loops	Input, process, output, and feedback loops are clearly and specifically explained.	Input, process, output, and feedback loops are explained.	Input and output loops are explained.	Input, process, and output loops are explained.	
CAD Drawings	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawings include relevant information but are missing dimensions.	The drawings are incomplete, but an attempt was made.	
Model	The Model and sketches are complete, with detail and labels.	The Model and sketches are complete, using labels.	The Model is complete.	The Model and sketches are incomplete, but an attempt was made.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disordered, or is confusing.	
Design Proposal/ Research Report	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demonstrating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	

Resources

www.trekbikes.com – Trek is a privately held corporation based in Waterloo, the small town in Southeastern Wisconsin where, in 1976, five employees started making handbuilt bicycle frames in an old wooden barn. Nearly a quarter century later, Trek is the world leader in bicycle products and accessories, with 1,500 employees worldwide.

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time *3-4 days*

Teacher Preparation

This case study will take three to four classroom days to complete. Students should be given at least three days' advance notice to obtain the appliance of their choice. These items could include such things as phones and radios. The suggestion is that students be paired off for this activity and be required to obtain one small appliance per group. (There are some small appliances that should be avoided, as they don't offer as many inner workings that can be evaluated and dissected.) Locations such as Goodwill and St. Vincent de Paul or any thrift store are good places to procure these items at a relatively low cost. Instructors may wish to purchase some of these items in advance of the dissection for students who may not be able to afford to purchase them on their own, or repeatedly forget to bring their items into the classroom.
Items needed for the dissection are:

- Permanent marker, wide
- Self-sealing bags
- Phillips screwdriver
- Slotted screwdriver
- Pliers
- Small appliance (supplied by student)
- Poster board
- Wire cutter

Safety

1. Use the hand tools only in the manner for which they were designed.
2. If your appliance has a vacuum tube, handle it with care. If one of these breaks, it will implode and can be very dangerous.
3. If your appliance has a cord, remove it and do not ever plug it into an outlet.

Case Study

Materials are usually things that society tends to pick off the shelf or purchase based on a known supply. Think of the material Kevlar. This material was not a viable solution to many manufacturers in the past, as it didn't exist. Scientists and engineers created it based on a need. Materials can be created based on parameters defined for a project. In our culture, a large number of small appliances are found around the home. These appliances are part of what technology has done to improve our lives. The materials used in these appliances are usually selected based upon availability, ability to serve the purpose, and economics. As you carefully dismantle the appliance, attempt to determine the purpose of each part and why the material that was used to make it was chosen.

Part A

1. Carefully dismantle the appliance, using the tools needed to remove the appliance's casing and inner parts. In this process, attempt to keep each of the parts intact. Note the type of appliance dismantled, your observations, and your impressions when dismantling it, in your journal.
2. Categorize the disassembled parts, and place them into containers or bags labeled metals, ceramics, polymers, and composites. Do this to the best of your ability.

Part B

1. Obtain a piece of poster board. Use the parts from your appliance to make a poster about your appliance. Use your creativity. The poster could include parts, historical developments, the appliance as you envision it in the future, an alternative to this appliance, etc.

Clean-up Instructions

1. The parts that are "junk" need to be placed in the area designated by your instructor. Recycle parts as needed, or as your community prescribes.
2. Tools must be returned to their proper places.

Assessment

1. Record information about your appliance and its parts. Include drawings and sketches. Don't forget to include what kind of appliance you dismantled.
2. Which of the four categories had the greatest number of parts? Why do you think this material was used for these parts?
3. Would you have used a different type of material for one of the parts? If so, what, and why?

Resources

Energy Concepts, Inc. (1999). *Materials Science Technology: Solids*. Pg. 2.23 – 2.25

Macaulay, David and Ardley, Neil. (1998). *The New Way Things Work*. Houghton Mifflin Company, Publisher. ISBN: 0395938473.

www.pnl.gov/education/mst.htm
This is the Web site for the Department of Energy's Materials Science Curriculum. The site also gives a glimpse into the full document with information and selected activities in PDF format.

www.eci-info.com
This is a national vendor that sells the reorganized Materials Science Curriculum so that it is more "teacher friendly." This curriculum covers many topics beyond the DOE curriculum.

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Texas Traffic

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *5-10 days*

Teacher Preparation

This case study will take five classroom days to collect data. It is suggested that you and your class spend a few days before the case study working with your school's spreadsheet program. There are books and multimedia available for all spreadsheet software programs. Students should be assigned to random groups of three for this group work. Each group will be assigned one of eleven major arteries in the city of Houston, Texas to research. Questions associated with the research in the assessment section will make this data (in a town they may not live in) relevant to your students. If your class meets at a time other than peak traffic times, use the archived data available on the site. This archived data or "historical data" should be used in conjunction with "real time data" in order to provide a custom report on the road that the team is assigned to.

Case Study

The Houston TranStar Automatic Vehicle Identification (AVI) traffic monitoring system is used to collect real-time information showing current travel conditions on Houston area freeways and high occupancy vehicle (HOV) lanes. This information is provided to personnel within the Houston TranStar Center for use in detecting freeway congestion. This travel information is also provided to the public through media reports, displays on selected roadside electronic message signs, and on the Houston TranStar Web Site (http://traffic.tamu.edu/).

The system uses Automatic Vehicle Identification (AVI) technology developed by the Amtech Systems Division of TransCore to collect the real-time traffic information. Houston was the first city to apply AVI technology for monitoring traffic conditions.

The AVI system operates through the use of AVI antennas and readers that are installed on structures along Houston area freeways. The AVI antennas and readers monitor the passage of vehicles equipped with transponder tags. The transponder tags are powered by a small battery, which enables them to reflect signals transmitted from the antennas/readers.

Texas Traffic

The system uses vehicles equipped with transponder tags as vehicle probes. The main source of vehicle probes is commuters using the "EZ-Tag" automatic toll collection system installed by the Harris County Toll Road Authority (HCTRA). Transponder tag readers are placed at one- to five-mile intervals along freeways and HOV lanes. Each reader senses probe vehicles as they pass a reader station and transmits the time and location of the probes to a central computer over a telephone line. As the probe vehicles pass through successive AVI readers, software calculates average travel times and speeds for a roadway segment. The averages are made available to software, which provides the data for the Houston TranStar Web site. In this case study, students will access the TranStar Web site (or your local Web site that has proper information) in order to study information and habits of drivers as well as "trouble spots" within a system. Breaking into groups of three, students should study the habits and mistakes of drivers over a five-day period. The team of students is required to collect and log major accident areas, major delay areas, and areas that they determine may be a future area of concern. There are eleven major arteries into and out of the Houston area. Each team will be assigned a specific road for data research.

Assessment

Students will be required to present their spreadsheets—and the charts derived from the sheets—to the entire class. They may choose to create large posters, PowerPoint presentations, or simply draw the chart on a chalkboard or whiteboard for the class. The presentation should include maps, charts, and pictures that explain the specific road that they researched as well as the main accident spots, slowdowns, and predicted future problem spots. The following questions should also be answered in written format by each member of the group:

- Identify the input, process, output, and feedback parts of this system.
- What are the pros and cons of this technology?
- How would you use it if it were available in your hometown?
- Could this technology provide a positive impact on your community? Why?

Resources

Holtz, Jane Kay. (1998). *Asphalt nation: How the automobile took over america, and how we can take it back*. University of California Press, Publisher. ISBN: 0520216202. This book is an excellent reference for alternative transportation methods and a bit of history on the automobile.

http://traffic.tamu.edu/ – This is the Houston TranStar Web site where the data can be downloaded and traffic can be observed. It also has links on how the technology works and many other topics that could be added to the lesson to make it more comprehensive.

www.dot.gov/about_dot.html – This page gives information about the Department of Transportation's organization, key officials, mission, and other important information related to managing the Department and accomplishing its mission.

www.microsoft.com/office/excel/default.asp – This is Microsoft Excel's homepage. It has tips and tricks, how to use Excel, and the top 10 frequently asked questions. If the site changes, search Microsoft's Web site, or try searching for your school's software.

Waste Management Systems

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *5-10 days*

Teacher Preparation

This case study will take five to ten classroom days to complete, depending on the complexity of the model that is required. Have students spend a day or two on the EPA Web site investigating additional materials regarding Municipal Solid Waste. The model that is built is for representation purposes only, and additional or more complex materials may be chosen to build your model. Construction materials are needed; these can be cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc. Your students will also need to download the Moon ABCs fact sheet from: www.spacegrant.hawaii.edu/class_acts/MoonFacts.html

Case Study

MSW (Municipal Solid Waste)—more commonly known as trash or garbage—consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries. In 1999, U.S. residents, businesses, and institutions produced more than 230 million tons of MSW, which is approximately 4.6 pounds of waste per person per day—up from 2.7 pounds per person per day in 1960.

Several management practices, such as source reduction, recycling, and composting, prevent or divert materials from the waste stream. Source reduction involves altering the design, manufacture, or use of products and materials to reduce the amount and toxicity of what gets thrown away. Recycling diverts items, such as paper, glass, plastic, and metals, from the waste stream. These materials are sorted, collected, and processed and then manufactured, sold, and bought as new products. Composting decomposes organic waste, such as food scraps and yard trimmings, with microorganisms (mainly bacteria and fungi), producing a humus-like substance.

Other practices address those materials that require disposal. Landfills are engineered areas where waste is placed into the land. Landfills usually have liner systems and other safeguards to prevent groundwater contamination. Combustion is another MSW practice that has helped reduce the amount of landfill space needed. Combustion facilities burn MSW at a high temperature, reducing waste volume and generating electricity.

In this case study, your team's objective is to design and build a model waste management system for a human settlement on the Moon. Here are the procedures for the case study:

1. Your school, in many ways, is like a miniature town. It has a system for governance, health care, traffic control, a work schedule for its inhabitants, recreation, AND waste disposal. To get a better idea of how much waste your school generates every week, find out how many people—students, teachers, administrators, other staff (and animals, if any) are regularly in the buildings.

2. Next, interview the cafeteria staff and the custodial staff for the answers to these questions:
   a. What gets thrown away?
   b. How many pounds get thrown away every week? Calculate how many pounds of trash this is for every person in the school.
   c. Are there any items that can be recycled before disposal? If yes, what are the recycled items?
   d. What items are biodegradable?
   e. In what is the garbage/trash packed for removal?
   f. Where is it taken?
   g. According to building codes, how many toilets must there be to accommodate all the people?

3. Waste is a "hot" topic in our society. Why? Discuss what you know about the following phrases: Excessive packaging, landfills, toxic waste, disposable plastic goods, non-degradable material, water pollution, and air pollution.

4. In movies like the "Indiana Jones" series, well preserved, ancient artifacts are often found in the desert. Scientists also find preserved artifacts in polar ice; for example, mastodons or ancient people. Why aren't they decayed?

5. Review the "Moon ABCs Fact Sheet." (www.spacegrant.hawaii.edu/class_acts/MoonFacts.html) The Moonbase must be an enclosed, self-sustaining settlement. Just like your school, it must perform the basic functions of a town. Other project teams are responsible for designing and constructing several other types of systems (air supply, communications, electricity, food production and delivery, recreation, temperature control, transportation, and water supply). Your team's job is to dispose of the waste that could be generated by these systems. Design a waste disposal system for the Moonbase. Be sure to decide what importance, if any, will be given to biodegradable materials, recycling, and the Moon area outside of the constructed settlement.

6. Construct a model of this system based on your design. It must include the application of at least four facts from the "Moon ABCs Fact Sheet." For example, how will the Moon's gravity affect the design of your system? Maybe your system will be very heavy but still portable by only a few

Moonbase workers because the Moon's gravity is only 1/6th Earth's gravity.

7. Make a detailed and labeled sketch of the model.

Assessment

Waste Management Systems Rubric

Category	Exemplary 5-4	Accomplished 3	Developing 2	Beginning 1	Score
Research	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demonstrating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	
Interview	All questions are accounted for and have valid, clear answers.	Most questions are accounted for and have valid, clear answers.	Most questions are accounted for.	Most questions are accounted for, but answers may not be valid or clear and defined.	
Phrases	Presents easy-to-follow information that is logical and adequately detailed.	Most of the phrases are understandable; some lack detail or are confusing.	Some of the phrases are understandable; most are confusing and lack detail.	Most of the phrases are missing, misordered, or definitions are all confusing.	
Model and Sketches	The model and sketches are complete, with detail and relevant materials and labels.	The model and sketches are complete, using relevant materials and labels.	The model and sketches are complete, using relevant materials.	The model and sketches are incomplete, but use relevant materials.	

Resources

Association of Municipal Engineers of the ICE. (1991). *Recycling Household Waste: The Way Ahead.*

American Society of Civil Engineers, Association of Municipal Engineers. (1991). *Recycling Household Waste: The Way Ahead.* Thomas Telford, Ltd., Publisher. ISBN: 0-7277-1650-6. This is a good book that is priced at $7 through the ASCE Web site (versus $52 from other sources).

National Aeronautics and Space Administration (NASA), Office of Human Resources and Education, Education Division Office of Space Science, Solar System Exploration Division. (1994). *Exploring the Moon: a teacher's guide with activities for earth and space sciences.* Grades 4-12. (This book is currently out of print.) ASIN: B00010L3U0.

www.spacegrant.hawaii.edu/ – Hawaii's Space Grant College, Hawaii's Institute of Geophysics and Planetology, University of Hawaii, 1996.

www.challenger.org/tr/tr_act_set.htm – The Challenger Center is committed to providing teachers with cutting-edge techniques to get students enthused about science and technology. Offers easily downloadable clipart and publications that can add visual excitement and hands-on activities to your lesson plan. When the subject is space, this is the place for news and resources to make every classroom minute count.

www.epa.gov/epaoswer/non-hw/muncpl/facts.htm – United States Environmental Protection Agency Web site.

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *3-4 days*

Teacher Preparation

This case study will take three to four classroom days to complete depending on the level of information that the teacher decides to present to the students before their experiment. The data collection should be done when the conditions outside permit. Within the experiment and data collection, everyday backpacks and books will be used to simulate additional loads that students carry around during the day. The data will be collected using no load, books loaded into a backpack, and books both in a backpack and in their hands. It is to be noted that alternative choices should be prepared for any students with physical conditions that will not allow them to participate in this experiment. Most students carry backpacks with books in them every day, so most should be able to participate.

The EKG breaks down each heartbeat into a series of electrical waves. Three of the waves, the P wave, the QRS complex, and the T wave, are associated with the heart's contractions. The P wave reflects the activity in the heart's upper chambers. The QRS complex and T wave reflect activity in the lower chambers.

Case Study

An exercise stress test is a special type of electrocardiogram (EKG) that compares the heart's electrical activity at rest and under exertion. The test is noninvasive, generally safe, and painless. A physician may recommend an exercise stress test for a number of reasons:

- To diagnose conditions such as coronary artery disease (a chronic disease in which there is a "hardening" or atherosclerosis of the arteries). Coronary artery disease can be diagnosed through an exercise stress test if it is causing cardiac ischemia (in which the heart is not getting enough oxygen-rich blood) and/or arrhythmias (irregular heart rhythms).
- To diagnose a possibly heart-related cause of symptoms such as chest pain, shortness of breath, or lightheadedness.
- To determine a safe level of exercise.
- To check the effectiveness of a balloon angioplasty (in which plaque in the arteries is pushed back against the artery walls to make more room for blood flow) or other procedures that have been done.
- To predict future risk of dangerous heart-related conditions, such as heart attack.

Depending on the results of the exercise stress test, the physician may recommend additional testing (e.g., a nuclear stress test) or a cardiac catheterization.

Students will complete a test, using their own backpacks and classroom books. This case study should be completed when conditions are acceptable for being outside.

1. Students should take their pulse at rest in the classroom after they have been sitting for at least five minutes. Log this rate in the data table on page 22.
2. Next, students should walk around the school block at a regular pace. The students should take their pulse when a full lap is completed. Log this data and the time it took into the data chart.
3. A backpack with books is now needed for the next step. Make sure to rest for about five minutes before going on the

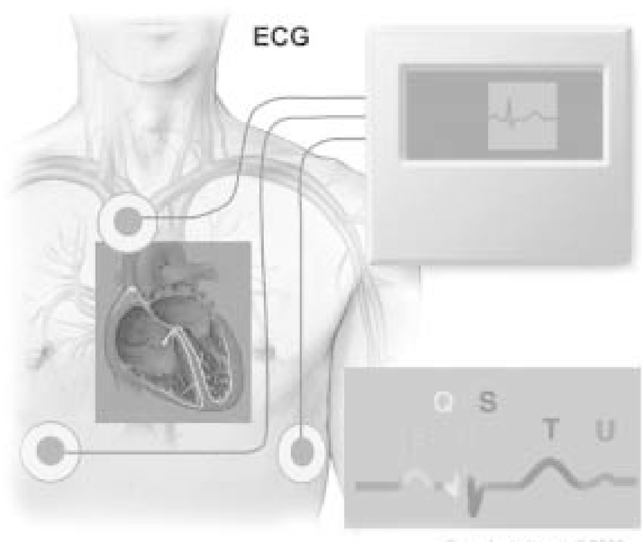

Illustration copyright © medmovie.com 2003. All rights reserved.

next walk. Students should now put their backpacks on and walk around the block, keeping track of the time it takes to complete one lap. At the completion of one lap, take your pulse and note the time it took to get around the lap. Log the data in the chart.

4. The final stage is to use the same backpack to complete the lap, with an additional load of books that are carried by hand by the students. Again, at the completion of one lap, take your pulse and note the time it took to get around this lap. Log the data in the chart.

Assessment

Students should complete the activity and chart for a grade (20 points). The instructor should develop a short quiz that reflects the vocabulary words from the above text (20 points). The students are then responsible for compiling the data in graphical format, using hand drawings or spreadsheet software such as Microsoft Excel. These charts can be pie charts, bar charts, etc. but must be organized and readable (50 points). Finally, the following questions should be answered:

- Why do doctors recommend stress tests? (See bulleted list on page 21.) (15 points)
- Chest pain, shortness of breath, and lightheadedness could be signs of what kind of disease? (Heart disease) (5 points)
- What should your normal resting heart rate fall between? (60-100) (5 points)

Resources

www.heartcenteronline.com

HeartCenterOnline provides a valuable service to patients with heart-related conditions and individuals seeking to minimize their risk of developing heart conditions. Their foremost objective is demonstrating their commitment to an individual's cardiovascular health and wellness. Because the HeartCenterOnline specializes in heart-related information and applications, they are able to:

1. Develop the best tools available to help people monitor their heart health.
2. Develop a comprehensive encyclopedia of original, cardiovascular, physician-edited cardiovascular information.
3. Arrange content into easy-to-access cardiovascular "centers," providing interactive resources, illustrations and animations, communities, current news, and feature articles on a wide range of heart-related topics.

The text, in part, is used with the permission of HeartCenterOnline.

Stress Analysis Data Table

Test number	Time to complete lap	Pulse rate
1 (at rest)	N/A	
2 (no pack)		
3 (backpack)		
4 (backpack and books)		

Academic Connections – Unit 1

Mathematics

- Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more complicated cases.
- Judge the reasonableness of numerical computations and their results.
- Approximate and interpret rates of change from graphical and numerical data.
- Analyze properties and determine attributes of two- and three-dimensional objects.
- Explore relationships (including congruence and similarity) among classes of two- and three-dimensional geometric objects, make and test conjectures about them, and solve problems involving them.
- Use trigonometric relationships to determine lengths and angle measures.
- Investigate conjectures and solve problems involving two- and three-dimensional objects represented with Cartesian coordinates.
- Draw and construct representations of two- and three-dimensional geographic objects, using a variety of tools.
- Visualize three-dimensional objects and spaces from different perspectives and analyze their cross sections.
- Use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest such as art and architecture.
- Make decisions about units and scales that are appropriate for problem situations involving measurement.
- Analyze precision, accuracy, and approximate error in measurement situations.
- Understand and use formulas for area, surface area, and volume of geometric figures, including cones, spheres, and cylinders.
- Apply informal concepts of successive approximation, upper and lower bounds, and limit in measurement situations.
- Use unit analysis to check measurement computations.
- Solve problems that arise in mathematics and in other contexts.
- Apply and adapt a variety of appropriate strategies to solve problems.
- Communicate mathematical thinking coherently and clearly to peers, teachers, and others.
- Recognize and apply mathematics in contexts outside of mathematics.

Science

- Identify questions and concepts that guide scientific investigations.
- Structure of atoms.
- Atoms and molecules.
- Structure and properties of matter.
- States of matter.
- Conservation of energy and the increase in disorder.
- Conservation of matter.
- Flow of matter in ecosystems.
- Flow of energy in ecosystems.
- Interactions of energy and matter.
- The cell.
- The molecular basis of heredity.
- DNA and inherited characteristics.
- Matter, energy, and organization in living systems.
- Energy in the earth system.
- Personal and community health.
- Disease.
- Diagnosis and treatment of mental and physical disorders.
- Culture affects behavior.
- Natural resources.

English

- *Lab reports*
  Students will link their English writing skills with this course through lab reports. The students should use complete sentences to describe their thoughts and actions during the activities.

- *Essays*
  These should be used as a tool to evaluate whether or not students have completed research. These may be given as individual assignments or could be included as part of a larger assignment. Instructors should develop grading criteria and inform the students before the essay is started.

Chapter 2, Unit 2

Technology/Society Interaction and Ethics

***Standards for Technological Literacy* Standards Addressed in Unit 2**

Unit 2 addresses the following *STL* standards:

- **Standard 3** Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
- **Standard 4** Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- **Standard 6** Students will develop an understanding of the role of society in the development and use of technology.

Big Idea

Relationship of Technology and Society

Student Assessment Criteria – Technology and Society

Achievement Level / Sub-concept	Above Target 3	At Target 2	Below Target 1
Change	**Insightfully compares** technological change, how humans influence technological development, and how individuals and society adjust to change.	**Compares** technological change, how humans influence technological development, and how individuals and society adjust to change.	**Compares, to a limited extent,** technological change, how humans influence technological development, and how individuals and society adjust to change.
Balance	**Thoroughly assesses** cost/benefits and trade-offs of different technological activities.	**Assesses** cost/benefits and trade-offs of different technological activities.	**Assesses, to a limited extent,** cost/benefits and trade-offs of different technological activities.
Impacts	**Thoughtfully analyzes** the extent to which a technological activity has accomplished its objectives, created new challenges, and generated new knowledge.	**Analyzes** the extent to which a technological activity has accomplished its objectives, created new challenges, and generated new knowledge.	**Analyzes, but with little depth,** the extent to which a technological activity has accomplished its objectives, created new challenges, and generated new knowledge.
Issues	**Critically assesses** the value of applying a technology and whether a given new technology should or should not be developed.	**Assesses** the value of applying a technology and whether a given new technology should or should not be developed.	**Assesses, but with little substantiation,** the value of applying a technology and whether a given new technology should or should not be developed.

Student Learning Experiences

Gilbane Gold
GPS Implants
Green Map Making
Recorded Music: Then, Now, and the Future
Political Contributions Ethics Debate

As a set of learning experiences, the following *STL* content standards and corresponding benchmarks are addressed: Standard 3, Benchmarks G, H, I, and J; Standard 4, Benchmarks, H, I, J, and K; Standard 5, Benchmarks G, H, I, J, and K; Standard 6, Benchmarks H, I, and J. However, if you choose to use only a specific activity, please refer to Appendix B to determine exactly which standards and benchmarks are being addressed by that learning experience. See **Appendix B** for a complete listing of the *STL* content standards.

Acceptable Evidence of Student Understanding

1. Document evidence of daily progress in a daily lab report or journal.
2. Identify ethical dilemmas within a scenario and respond to the issue(s).
3. Research and propose a relevant application for GPS implants.
4. Create scale models and drawings for proposed solutions.
5. Design a green map of a community.
6. Draw conclusions based on observations of the environment as it relates to a green map.
7. Identify issues in the environment that could be negative to the community that surrounds it.
8. Document the history of recorded music.
9. Develop a survey for adults regarding ways they play back recorded music.
10. Develop a model or prototype of a group-proposed solution.
11. Develop a marketing plan for a group-proposed solution.
12. Participate in a debate on ethics based on the NSPE code of ethics.

Special note: Please keep in mind that criteria must be developed to measure the evidence that students provide in demonstrating their levels of understanding—what are we looking for and how will we know it when we see it? For example, if students are asked to build a model, how will we know if it's a good one?

When considering achievement levels and helping students to understand how they might improve, it will be necessary to know what we mean by terms such as effectively, efficiently, adequately, creatively, thoughtfully, mostly, clearly, minimally, marginally, correctly, safely, systematically, randomly, logically, thoroughly, introspectively, insightfully, and meaningfully. (See **Appendix D, Acceptable Evidence Glossary**, for definitions.)

Overview

When developing a new technology, engineers and technicians must consider the impact of that technology on society. When considering the new technology, two types of decisions must be made.

A Cost/Benefit Analysis: Does the cost justify the product? Cost/benefit analysis is an easy technique to use, and it is used in many different fields. This helps businesses and organizations decide if they should move in one direction or another. When the choice is made to use this technique, a company would add up the benefits of a course of action and subtract the costs associated with it. Costs can be a one-time event, or can be spread out over time. Benefits are usually associated with long-term measurements. Time is an effect of the analysis and can be built into the analysis by using a payback period. The time it takes for the benefits of a change to repay its costs is a payback period. It is usually a good choice to determine a specific period of time to look for payback. An example would be a computer system that is to be purchased for a company for $30,000. If the payback period is five years, the system costs $6,000 for each of those first five years, and then it is paid for. The question the company needs to ask is if it will still be current five years from now, or if it will be outdated in three years. The company can now analyze whether the system should be purchased or if an alternate solution should be proposed.

A Risk/Benefit Analysis: Does the risk of building the product outweigh the negative societal impact? Risk analysis is a way to help an organization assess the risks that it faces. When a company decides to enter into a risk analysis, caution should be used in order to keep focus on the goals and intents of the original plans that were made. These cautions will produce strategies used to control risks and keep the study cost-effective. The definition of risk is "the perceived extent of possible loss." Because we all have different opinions and come from different "schools of thought," what one person perceives as a minimal risk might be something that another cannot possibly fathom.

Risk = probability of event x cost of event

An ethics statement from the Engineers Council for Professional Development says, "Engineers shall hold paramount the safety, health, and welfare of the public in the performance of their professional duties." Engineers and technicians must uphold and advance the integrity, honor, and dignity of the engineering profession. The National Society of Professional Engineers (NSPE) presents case studies to the board, and they discuss the issues and make decisions.

Engineering ethics is (1) the study of moral issues and decisions confronting individuals and organizations involved in engineering and (2) the study of related questions about moral conduct, character, ideals, and relationships of peoples and organizations involved in technological development (Martin and Schinzinger, *Ethics in Engineering*).

Teacher Preparation

The following general suggestions will help the teacher prepare for instruction in this unit. To begin, review the technological literacy standards and academic connections for this unit. You may want to meet with the math and science teachers in your school or school district to obtain input for the content in this unit and additional resources for the class. Another suggestion is to contact local businesses or engineering experts to get another perspective on the unit content and activities. Locate the resources recommended at the end of each case study and review their content.

You may want to introduce this unit by pointing out recent technology-related issues and events cited in the national or local newspaper. Prepare questions that will engage students in a discussion of the potential impacts of these issues locally and globally.

Unit 2 Content Outline

I. Technology/Society Interaction and Ethics
   A. Technology/Society Interaction
      1. Technology is both a cause and a result of scientific activity.
         a. Tools created by technology are used by scientists.
         b. Scientists have needs that, in turn, create tools.
      2. Society influences and responds to engineering.
      3. Society controls technological development.
         a. Could big corporations be assisting disease-stricken third world countries for "face value"?
         b. European markets are much more open to the introduction of new products.
            1.) Americans are much more likely to fear any type of risk in a new product and more likely to bring about a lawsuit if something unplanned occurs.
      4. Historical events have shaped, and will continue to shape, technologies.
         a. Man on the moon
         b. Exxon-Valdez oil spill
      5. Scientific and technological issues are influenced by values.
      6. Technology has positive and negative effects.
         a. Internet banking
         b. Nuclear power
         c. Coal
         d. Gasoline
         e. Electric cars (need electricity – An electric car doesn't pollute the environment, but the process of making the electricity does.)

Unit 2 Content Outline, continued

7. Some developments have no projected negative or positive effects.
    a. Lasers
    b. GPS Implants
8. Politics plays a role in design.
    a. Lobbyists spend time and monies for specific companies and products.
    b. Products may get approval because of pressures.
    c. Smaller ideas with no political influence may not come to light.
        1.) These small business solutions may actually be far superior to other solutions.

B. Ethics
1. Professional and legal responsibilities
    a. Engineers take an oath similar to the Hippocratic oath for doctors.
    b. Guidelines for professional conduct
    c. Contractual obligations
    d. Legally bound to live up to the performance standards specified
2. Social responsibilities
    a. Design and implement with a social conscience
    b. Inform their publics about the risks
3. Ethical dilemmas
    a. Might place their own personal or professional values in conflict with those of employers or clients.
    b. Engineering decisions may involve making trade-offs.
    c. When do engineers stop increasing safety or quality, and accept an increased risk to human life or the environment?
4. Whistle-blowing
    a. Conflict between a company practice and their own social conscience
    b. Notify someone outside the company
        1.) Newspaper
        2.) Television
        3.) Regulatory agency
    c. Attempt to bring public pressure
    d. Clear detrimental effects on both the company and the individual
    e. Roger Boisjoly
        1.) Morton-Thiokol
        2.) O-ring seals on the Challenger rocket booster
    f. Bay Area Rapid Transit (BART) system
        1.) Engineers were fired.
        2.) The press publicized the issue.
        3.) BART train malfunctioned because of the problem pointed out.
        4.) Engineers received award for outstanding service in the public interest.
5. Resolving ethical dilemmas
    a. Raise their concern with the management
    b. Create channels for internal discussion of the issues
    c. Respect the engineer's anonymity
        1.) McDonnell Aircraft solutions
        2.) Raytheon Corporation solutions
6. Code of ethics
    a. The Fundamental Principal
        1.) Engineers uphold and advance the integrity, honor and dignity of the engineering profession by:
            a.) Using their knowledge and skill for the enhancement of human welfare.
            b.) Being honest and impartial, and serving with fidelity the public, their employees, and clients.
            c.) Striving to increase the competence and prestige of the engineering profession.
            d.) Supporting the professional and technical societies of their disciplines.
    b. The Fundamental Cannons
        1.) Engineers shall hold paramount the safety, health, and welfare of the public in the performance of their professional duties.
        2.) Engineers shall perform services only in the areas of their competence.
        3.) Engineers shall issue public statements only in an objective and truthful manner.
        4.) Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest.
        5.) Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.
        6.) Engineers shall associate only with reputable persons or organizations.
        7.) Engineers shall continue their professional development throughout their careers and shall provide opportunities for the professional development of those engineers under their supervision.

Suggested Learning Activities

These suggested activities support the content for this unit. The teacher may use alternate activities, but care should be taken to see that these activities reflect the specified content and address the *STL* content standards listed at the beginning of this Unit.

Gilbane Gold

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *2 days*

Teacher Preparation

This case study will take two classroom days to complete. Students will be introduced to the case study through a reading in which the entire class will participate. The class will then watch the companion video, available from the National Institute for Engineering Ethics (www.niee.org). This 20-minute video will walk the class though a scenario about which they will have to individually answer questions. The grades given for this type of case study should be pass/fail in nature, as putting a subjective grade to an ethics question will typically send up some red flags. The questions have been developed by the NIEE and relate to students' opinions on the actions of the characters.

Case Study

This case was originally prepared by the National Institute for Engineering Ethics of the National Society of Professional Engineers. It is a fictional but highly plausible case, suggested by actual situations. Engineers will find it easy to identify with the junior environmental engineer, David Jackson, who is caught between his desire to be a good employee and his sense of obligation as an engineer to protect the health, safety, and welfare of the public.

Although the primary ethical issue raised in the case is whistle blowing, secondary ethical issues include the obligations of engineers with respect to environmental issues, management problems having to do with honesty and trust between business and its host community, the issue of the fairness of a community toward local manufacturing plants, the problems raised for individuals and groups by the necessity for action in the face of inconclusive scientific evidence, and the relationship of law and morality.

The case takes place in the imaginary town of Gilbane. The sludge from the Gilbane sewage plant has been used for many years as a fertilizer and is sold under the name "Gilbane Gold." The revenue from the sale of Gilbane Gold enables the city to supplement its tax revenues, saving a family of four approximately $300/year in taxes. In order to protect this source of income, the town placed severe restrictions on the discharge of heavy metals into the sewage, so the sewage would be safe for use by farmers as fertilizer. The restrictions are ten times more stringent than federal regulations.

Before implementing these regulations, Gilbane had aggressively marketed itself as a city with a good business climate, offering tax abatements to industries that chose to move there. After several high-tech firms moved to the area, the more stringent regulations were enacted. Z CORP was one of the companies that moved to Gilbane. Its Gilbane plant manufactures computer components, but the plant's manufacturing process creates substantial quantities of toxic materials, primarily heavy

Logo published with permission of the National Institute for Engineering Ethics.

The National Institute for Engineering Ethics (NIEE) is an official component of the Murdough Center for Engineering Professionalism in the College of Engineering at Texas Tech University. NIEE was initially created by the National Society of Professional Engineers (NSPE) in 1988 and later became an independent organization in 1995.

metals. Z CORP monitors its waste discharge monthly.

Two facts about the regulations affect the resolution of the case. First, plants in Gilbane are responsible for supplying test data to the city. The data must be signed by an engineer, who attests to its accuracy. The law governing effluents is flawed, however, for it only regulates effluent discharge in terms of the amount of toxic material for a given volume of discharge, not in terms of the total quantity of contaminant. So a plant can always operate within Gilbane standards by simply increasing the volume of discharge.

Second, a newer and more sensitive (but also more expensive) test for heavy metals has been developed since the city enacted its standards. The newer test is not required by the city, and the city of Gilbane does not use it. Z CORP employees have access to the test, and it shows that the plant has apparently been slightly exceeding the allowable emissions on a number of occasions. This produces a problem for Z CORP. If it discloses the results of the new test, the city might take legal action against it. If it does not disclose the results, some of its own employees may believe it is exhibiting bad faith with the city.

The plant's junior environmental engineer, David Jackson, is a new employee. He has replaced a consultant who believes he was released because of his warnings about the discharge of toxic materials. David is concerned about Z CORP's heavy metals discharge, and his concern is further intensified when he learns that Z CORP has signed a contract that will result in a five-fold increase in the discharge of heavy metals. David finally decides to blow the whistle on the plant's discharge levels by talking to the local TV newscaster.

Assessment

Questions for discussion:

1. In what ways does the fact that David's boss is not an engineer affect David's actions?
2. Do you think Z CORP is "poisoning" the soil at present levels of discharge? What about a 500% increase?
3. Do you think the city is treating Z CORP unfairly? Should it bear some of the expense of complying with its strict effluent standards?

Questions for individuals:

1. Does the presentation of the case by Maria Renato affect the decision made by David Jackson?
2. In what ways does the fact that David's boss is not an engineer affect David's actions?
3. Does Prof. Massin add any insight into what actions David should perform? That is, would you look to a former professor to help you deal with an ethical issue?
4. If you were David, would you look to your professional society for advice on how to handle the situation?
5. The plant manager is presented with conflicting reports from her employees. How could David have presented his concerns more effectively to the plant manager?
6. Do you think David is deceiving the city if he does not reveal the results of the new test? Regardless of whether he is deceiving the city, is failing to reveal the results of the new test justified?
7. Do you think Diane's actions are unfair to David?
8. Do the actions of the ex-consultant Tom Richards seem in any way to have ulterior motives?
9. Does David have any other options that he did not consider?

Each student should answer the questions in full, noting that, if there is a relevant answer, points should be assigned for that question. If a student leaves a question blank or the answer is not relevant to the question, then no points for the question are awarded.

Resources

www.nspe.org – The National Society of Professional Engineers (NSPE) is the only engineering society that represents individual engineering professionals and licensed engineers (PEs) across all disciplines. Founded in 1934, NSPE strengthens the engineering profession by promoting engineering licensure and ethics, enhancing the engineer image, advocating and protecting PEs' legal rights at the national and state levels, publishing news of the profession, providing continuing education opportunities, and much more. NSPE serves some 60,000 members and the public through 53 state and territorial societies and more than 500 chapters.

www.niee.org – The National Institute for Engineering Ethics (NIEE) gives a discount to educational institutions for the Gilbane Gold video—they charge $92 plus $8 shipping and handling. This price also includes a study guide for the video. Gilbane Gold can be purchased by contacting:

National Institute for Engineering Ethics
Box 41023
Lubbock, TX 79409-1023

Email: ethics@niee.org
Ph: 806-742-NIEE (6433)
Fax: 806-742-0444

The text description and questions from Gilbane Gold are published with the permission of the National Institute for Engineering Ethics.

GPS Implants

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *7-10 days*

Teacher Preparation

This case study will take seven to ten classroom days to complete entirely. The teacher may extend the period of time in order to present additional information at the front end of the case study. Teachers can find additional information online about implants and GPS systems that may be relevant to the classroom experience.

Case Study

"Big Brother" was brought to bear in the late 1940s, with George Orwell's *1984*. We are and will continue to be a technological society that strives to know everything. The thought of someone or something always watching your every move doesn't sit well with many global citizens. It is fair to say, though, that if someone were in extreme circumstances they would want to be able to be found or seen by relatives or the authorities. Imagine your grandfather, suffering from Alzheimer's. Should your family make the choice to fit him with an implant to guarantee his safety should he need medical treatment when there was no one around? These devices can record information, such as home address and medical information, that would be beneficial when scanned in a hospital. Would this kind of technology help parents keep track of their toddlers and young children? Could it prevent children from being kidnapped at all? Obviously the decisions have to be made by individual families to have this type of procedure done.

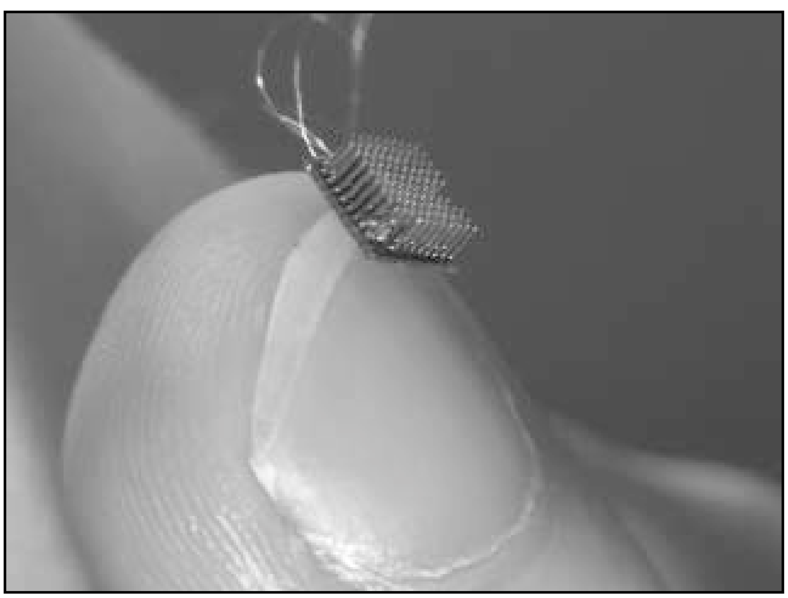
Photo courtesy of iCube Solutions.

With the advance of technology, newer devices will always become available. Microchips are beginning to be designed for affordable implementation. Due to their very small size, microchips are suitable for placement in animals, humans, wearable objects, vehicles, and many more areas. Their uses vary from GPS (Global Positioning System) location to carrying medical information. UPS and FedEx use similar GPS devices to help track shipping information.

The difficulty with many of these devices is a common attitude of loss of privacy. Many of them may be used for identification and informational purposes. Global citizens are reluctant to carry devices that will be capable of immediately providing their personal information to government and private industry.

Your team of three has been charged with deciding where to implement the uses of these devices. Your task is to research microchips, possible locations for use of microchips, and to finally propose an application for this technology. The device that is designed can be used in the public or private sector but must have a significant market that doesn't currently exist. The design must include:

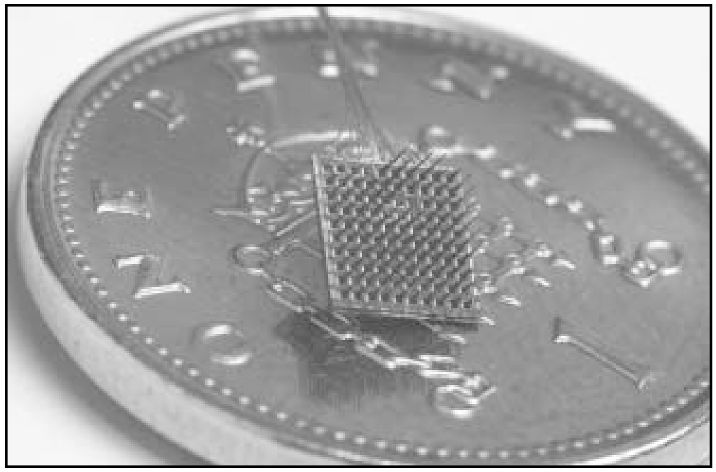

Photo courtesy of iCube Solutions.

1. Research report
   a. The primary use
   b. Listings of the pros and cons
   c. Any ethical dilemmas that need resolution
   d. Directions for use
   e. A cost/benefit analysis
2. A scale model of the device
3. An electronic (PowerPoint) presentation
4. A Computer Aided Drawing of the microchip AND the object in which it is planted
   a. Dimensions of the device to be included

Assessment

A sample rubric for the activity is listed below. Instructors can add requirements as they see fit; however, the instructor should consult students before the project starts in order to develop a final rubric and set of rules.

GPS Implants Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Research	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demon-strating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	
Scale Model	The model and sketches are complete, with detail and relevant materials.	The model and sketches are complete, using relevant materials and labels.	The model and sketches are complete, using relevant materials.	The model and sketches are incomplete, but use relevant materials.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disor-dered, or is confusing.	
CAD Drawing of Device and Host	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawing includes both device and host, with missing information or dimensions.	The drawings are incomplete, but an attempt was made.	

Resources

www.glpbooks.com – Great Lakes Press Web site.

El-Rabbany, Ahmed. (1996). *Introduction to GPS: The Global Positioning System*. Artech House, Incorporated, Publisher. ISBN: 0890067937 An introduction to the Global Positioning System that accomplishes its task without the need for advanced mathematics. Emphasizing GPS applications, the book describes its signal structure, the types of measurement currently in use, and errors affecting these measurements. Recommendations for minimizing errors and integrating GPS technology with other systems are also included. Seventy-five illustrations are featured.

www.kevinwarwick.com/ – In 1998 Kevin Warwick shocked the international scientific community by having a silicon chip transponder surgically implanted in his left arm. A series of further implant experiments have taken place in which Kevin's nervous system was linked to a computer.

www.digitalangel.net/ – The exclusive licensee under U.S. patents for Personal Tracking and Recovery Systems and In-building Location Systems. Marketer of the first consumer safety and location system that combines GPS location and biosensor technologies as well as provides phone and e-mail alerts to subscribers. The worldwide leader in pet recovery, with approximately one million pets in the U.S. and over ten million in Europe protected by patented microchips.

Case study reprinted from "Engineering Your Future, A Project-Based Approach" with the permission of Great Lakes Press, Inc., PO Box 550, Wildwood, MO 63040-0550.

Green Map Making

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *7-10 days*

Teacher Preparation

This case study will take seven to ten classroom days to complete depending on the complexity of the maps assigned. Be sure to determine whether your class groups will focus on the same area within your school's neighborhood, or if a wider area will be split up into sections for each group to research independently. It should be noted that, if you are in a large urban area, it might be difficult for students to split up and cover different areas of the city. Your local city engineering (or planning) department is a great source for maps and information. Many of these departments will use computer drawings for their maps, and copies might be available for your use. Other sources for maps of your community might be bus route maps, tourism offices, or the Internet.

Check the library for books on local tourism, and natural and cultural history. Check with community and governmental offices, including Planning Boards and the Parks Department, to find out who is working "behind the scenes" for conservation and a healthier environment. Check bulletin boards for information on eco-events and group meetings that might lead you to find more green sites or help discover greening initiatives already underway in your community. From the onset of the project, consider how users will navigate the map once it is completed, as well as the most effective ways to draw attention to the important features of your map. The overall visual appearance of the map itself is important.

A non-profit company that promotes sustainable communities, GreenMap System has offered their adaptable framework to all educators using *Engineering Design*. GMS's Web site (www.greenmap.org) has additional materials, definitions of sustainable sites, etc., and the organization can provide a resource disk and its award-winning icons as a font (nominal fee). You can also send in copies of your finished Green Maps and pictures of youth at work. These will be included on GMS's Web site and become part of their network of youth Green Mapmakers. GMS would like you to share lessons learned with other teachers; please contribute in any way you can to their non-profit organization and impact communities around the world.

Case Study

Green Maps give us a fresh perspective of our cities and towns. They help us locate eco-resources such as bike lanes, farmers markets, and wildlife habitats, along with cultural sites that make our hometowns special. Green Maps encourage us to discover new ways to experience the local urban ecology. Every city has many wonderful places where you can get involved in creating a more natural and enjoyable lifestyle. Find out ways to put the places and things you like about the local environment "on the map."

Each mapmaking team of three people should start by choosing an area to explore. This area should be either one that is familiar or one that is designated by the class. Draw or study a map showing landmarks and crossroads of the built environment, including streets, parks, and gardens. Discuss the target audience—neighbors, city residents, tourists, students, planners and policy makers—and the general outline and goals for your Green Map. Consider where your map will be displayed and distributed when completed. Your introduction should include issues of concern to youth regarding the community's environmental health and cultural resources.

Scout around your area and find places described by the Icons (download from the Web site) or use the worksheet your teacher gave you. While you are in the field, use notebooks or index cards to keep track of the category, name, and location of each green site. The first identifiable areas should be: Green businesses, eco-smart transportation, recycling reuse sites, cultural and historic places that make your community special, natural areas, habitats, and gardens. What other sites are important? Are there toxic hot spots, blight sites, or issues that are most important for you to raise awareness about? Put these on your Green Map, too.

Each team should discuss the green sites it found and decide which of the Icons describe them best (use more than one, if necessary). Compare your sites to the descriptions on the Icon sheet. In addition, you can collect notes on noises and smells, as well as share general impressions about the health and physical beauty of an area's environment.

Write a short survey to help gather more information from local residents, shopkeepers, and other community members about wildlife, significant organizations, public transportation, cherished cultural sites, and other green places in your area. Do different age groups suggest different kinds of sites?

All members of your Map team should compare the lists of green sites they've discovered. Share your combined list with your class and community. Are there any categories you missed? Do you need more research? Should more recreational, cultural, or historical places be included? Are you ready to compile a final list?

If you have not already done so, draft your map by tracing a base map or drawing a diagram of your area that fits the size of your paper. You can work freehand, trace an aerial photo, or copy an existing map. Be sure to credit the source of the base map, which may be a road map, a lot survey plan, a city planning map, etc.

Use a copy machine or tracing paper and create a "working map." Try to use colors, the icons, and design elements that will enhance the map but will also reproduce well. You can select colors for the icons, but make sure they stand out clearly. Plot the icons in the appro-

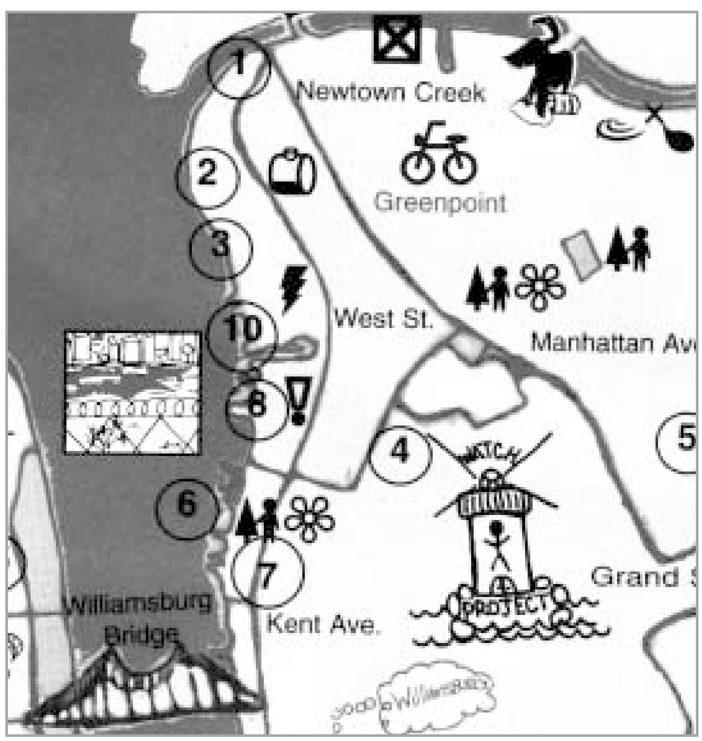

Image courtesy of Modern World Design, assignor to Green Map System, Inc.

priate places on your map. To identify each site by name, you can either:

1. Put the site's name right on the map next to the icon,
2. Number each icon on the map, then put a numerical list on the side, or
3. Number the map, then put both icon and site name in a list on the side. Include the site's contact information and coordinates.

Please include:

- An arrow pointing North, the scale of the map, and the date of creation.
- A list of the members of your mapmaking team and the sources for your information and base map.
- The Green Map System's copyright for the icons (Copyright GreenMap System, Inc. all rights reserved). You can also add the logo.
- A title block or logo for your Green Map, as well as your own copyright (if desired) and your contact information.
- Leave a white border (at least 3/8 inch) all the way around the map.

When everything has been placed on your working Map, and you are happy with its appearance, copy or trace over it to create a clean finished Green Map. If it is to be printed, special preparation will be needed. A computer-based map can also be created, using graphic design, desktop publishing, or GIS (geographic information systems) software.

Once the Green Map is nearing completion, you should consider strategies for sharing your findings with your school community, other schools nearby, community groups, and elected officials. Send or deliver Green Maps, or your Web-based Map's address, to friends, relatives, the green businesses (and other sites) listed on your Map and newspapers or the media. Include a press release or other background information about your project.

Assessment

The instructor should use the following questions to develop a written assignment for students. The written report includes portions that are self-assessment, data analysis, and forecasting (100 points). The map that is created is also a graded portion of this assignment and should be given point values that are approximately ¼ of that for the reports (25 points). Each student should rate his or her teammates (not themselves) with a percentage of 100. This averaged percentage should be multiplied by the number of points received by the group to get the individual's grade. The chart below is an example.

As the instructor, you should verify the math, and whether the individual deserves the final calculated grade. Based on your observations of the case study, you may then opt to raise or lower the grade accordingly. What follows are the sample questions that the group report should cover:

1. Draw some conclusions from the work you have done. What are some important observations you can make about the relationship between nature and our cultural (built) environment?
2. What new things have you learned about the place where you live?
3. What was your favorite part about making the Green Map? What surprised you the most? What was the strangest thing you learned about your community's environment? What was the most difficult?
4. How does the number of green sites in your community compare with toxic hot spots, blight areas, or other problem sites? Can you think of ways to tip the balance so you'll have a

	Joe	Mary	Steven
Peer Evaluation	100 95	95 95	90 95
Average	97.5	95	92.5
Group Grade on Project	120/125	120/125	120/125
Individual Grade Group x %= Final Grade	120 x .975= **117**	120 x .95= **114**	120 x .925= **111**

healthier, greener community? What can you, personally, do to change things for the better?

5. How would you like to see your community's environment change for future generations? Whose job it is to make sure that it becomes healthier and more sustainable?

Resources

Davis, MacKenzie L. & Corwell, David A. (1997). *Introduction to Environmental Engineering.* McGraw-Hill Companies. ISBN: 0070159181.

www.greenmap.org – The Green Map System is a globally connected, locally adaptable eco-cultural program for community sustainability. Green Maps (both printed and online) utilize Green Map Icons to chart the sites of environmental significance around the world. Visit the Web site to see youth-made Green Maps and more resources for educators.

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Recorded Music: Then, Now, and the Future

Content: *Nature and development of technology, Technological progress, Rate of technological development*

Time: *4-7 days*

Teacher Preparation

This case study will take four to seven classroom days to complete, depending on the depth of the culminating assignment. Students should be separated into groups of three at random for this case study. The students should be presented with information on the history of recorded music and the media on which it has been and is being distributed. There is a brief description of Emile Berliner's and Thomas Edison's inventions below; however, the teacher should provide additional information to the students in order to provide a well-rounded lesson.

The groups will be assigned several portions for this case study. First, they will have to document the history of recorded music as presented by the teacher in class, with additional information provided by student research. Second, the groups should be given the set of prescribed questions listed below. The teacher may choose to develop additional questions as a class, or let each group develop the additional questions to be used in the survey. The additional questions should be relevant to the development of a possible new solution to the way music is replayed by the general public. The last piece of the case study is for the groups to develop mock-ups or models of what their solutions would be. Data, drawings, and a short marketing plan is also required of the groups, as they will be required to give formal presentations to the entire class.

There are a few Web sites as well as a book by Timothy Day listed in the resource section that are good starting points for the history of recorded music. Additional publications and Web sites do exist; the suggestion is that all source possibilities be investigated before beginning this case study.

Case Study

The history of recorded music has seen incredible technological advancements since Emile Berliner and Thomas Edison simultaneously invented their recording devices in 1877. Mr. Berliner developed and patented the cylindrical and disc phonograph system. Mr. Edison invented the phonograph. In order to record with a phonograph, an indentation on a moving strip of paraffin-coated paper tape was made by means of a diaphragm with an attached needle. This mechanism eventually led to a continuously grooved, revolving metal cylinder wrapped in tin foil.

Since the 1950s we have seen the marvels of 78s, 45s, LPs, 8 track tapes, cassette tapes, Digital Audio Tape (DAT), Compact Discs, Mini-Discs, and MP3s. The future

Shawn Fanning wrote the code to help his friends find more MP3s online.

of recorded music will surely take new form in years to come as the demands of consumers keep the music industry an integral part of our culture. The research and development divisions of major corporations will continue to introduce and invent “better” technologies for consumers to recreate this music wherever they are in the world. From inside our personal vehicles to our work establishments and back home, technology is all around to introduce sound into the air.

In this case study, your team will study the effects of technology on society. The interaction between technology and humans is ever apparent in recorded music. Some “experts” think that digital music eliminates some of the contents of the artist’s original work. Others believe that the developments in recorded music have increased our ability to replay music in more convenient ways, with less space used for storage and equipment.

Survey at least 25 adults (18 or older), asking several questions that are prescribed and several that are developed by your team. One of the objectives of the case study is to define what types of technology adults use to replay music. The additional questions developed by your team should be used to develop a hypothesis of what type of technology could be developed for the future.

Your team should develop a mission statement and a series of mock-ups or models of systems and products, with drawings and data, that could be proposed to consumers. The prescribed questions that should appear in the survey are as follows.

a. Age and gender
b. What medium do you currently use to play back music?
c. How many different mediums have you used in your lifetime?
d. What is your biggest complaint about the current medium you use?
e. Were there any good things about the previous mediums?
f. What do you think would improve the way music is stored and replayed?

Recorded Music: Then, Now, and the Future Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Research	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demonstrating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	
Mock-up or scale model	The mock-up or scale model is complete, with detail and relevant materials and labels.	The mock-up or scale model is complete, using relevant materials and labels.	The mock-up or scale model is complete, using relevant materials.	The mock-up or scale model are incomplete, but use relevant materials.	
Survey of Adults	All questions are clearly stated and have relevance to the case study.	Most questions are clearly stated and have relevance to the case study.	Questions are stated and have some relevance to the case study.	Questions are stated, but may not have relevance to the case study.	
Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disordered, or is confusing.	
CAD Drawing of device	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawing includes both device and host, with missing information or dimensions.	The drawings are incomplete, but use relevant materials.	

Assessment
Students will be required to submit their work and research at the end of the presentation to the class. Required for submission are:

1. Research on the history of recorded music.
2. Student-developed, relevant questions for the survey of adults; questions must be relevant to the development of a future-looking technology to replay music or recoded selections.
3. Mock-up or model of the device.
4. Short marketing plan.
5. Data and scale CAD drawings.
6. Presentation.

Resources

Day, Timothy. (2000). *A Century of Recorded Music: Listening to Musical History*. New Haven, CT: Yale University Press.

Jones Media and Information Technology Encyclopedia. Audio Recording: History and Development. www.jonesencyclo.com/

Library of Congress. Emile Berliner and the Birth of the Recording Industry home page. http://memory.loc.gov/ammem/berlhtml/berlhome.html

Roxio, Inc. The Roxio Web site. www.napster.com

Political Contributions Ethics Debate

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *1-3 days*

Teacher Preparation
This case study will only take one classroom hour to complete; however, the teacher should assign a specific scenario to be debated within the class. Students will be responsible for researching each stance on the scenario, whether they think it is right or wrong. On the day of the debate, students should be split according to their strong views on the case. If there is an unequal number of students on either side of the issue, they should be equaled out by the instructor (this is why they were asked to research both sides of the story). A debate should then be facilitated by the instructor, noting that it may take a bit of cajoling to get the conversations started. This won't last long, as the emotions of the students defending their positions will grow stronger as people defend the opposite view. Each student should participate in the debate, and then points should be assigned for participation only. This assessment is pass/fail evaluation only. It is strongly suggested that the teacher not use subjective evaluation to grade this activity.

Case Study
Engineer A is the principal in a small-sized consulting engineering firm. Approximately 50% of the work performed by Engineer A's firm is performed for the county in which the firm is located. The value of the work for the firm is estimated to be approximately $150,000 per year. Engineer A is requested to make a $5,000 political contribution, the maximum amount allowed by law, to help pay the cost of the media campaign of the county chairman.

After subsequent thought, Engineer A makes a $2,000 contribution to the campaign of the chairman, a person Engineer A has known for many years through mutual public service activities as well as their activities on behalf of the same political party. The county board chairman serves in a part-time capacity and receives $9,000 per year for his services. Other members of the board receive $8,000 per year for their services. As required under the laws of his state, Engineer A reports the campaign contributions to the state board of elections, and correctly certifies that the contributions do not exceed the limits set by the law of the state.

These contributions and the contributions of other firms in the county are reported by members of the local media who appear to suggest that Engineer A and other firms have contributed to the campaign in anticipation of receiving work from the county. Engineer A continues to perform work for the county after making political contributions.

Group debate question:
Is it unethical for Engineer A to continue to perform work for the county after making the $2,000 contribution to the campaign of the county board chairman?

Assessment

Each student should participate in the debate, and then points should be assigned for participation only. This assessment is pass/fail evaluation only. It is strongly suggested that the teacher not use subjective evaluation to grade this activity.

Resources

NSPE Case 73-6

For many years, the engineering profession has been grappling with the ethical issues involved with political contributions by individuals to state and local candidates. Political contributions were the subject of a keynote address by the National Society of Professional Engineers (NSPE) at a recent national meeting and continue to be examined by a special task force charged with developing a political contributions policy.

References: NSPE Code of Ethics

Section II.3.a.

"Engineers shall be objective and truthful in professional reports, statements, or testimony. They shall include all relevant and pertinent information in such reports, statements, or testimony."

Section II.5.b.

"Engineers shall not offer, give, solicit, or receive, either directly or indirectly, any political contribution in an amount intended to influence the award of a contract by the public authority, or which may be reasonably construed by the public as having the effect or intent to influence the award of a contract. They shall not offer any gift or other valuable consideration in order to secure work. They shall not pay a commission, percentage, or brokerage fee in order to secure work except to a bona fide employee or to bona fide established commercial or marketing agencies retained by them."

Section III.1.f.

"Engineers shall avoid any act tending to promote their own interest at the expense of the dignity and integrity of the profession."

Martin, Mike, Chapman University, F. E. Warren AFB & Schinzinger, Roland, University of California-Irvine. (1996). *Ethics in Engineering, Third Edition.* ISBN: 0-07-040849-1.

www.mindtools.com – Mind Tools Web site. Mind Tools' mission is to help you understand the essential skills and techniques that will help you to excel, whatever your chosen profession.

The case study was published with the permission of the National Society of Professional Engineers.

Academic Connections – Unit 2

Mathematics

- Judge the reasonableness of numerical computations and their results.
- Approximate and interpret rates of change from graphical and numerical data.
- Make decisions about units and scales that are appropriate for problem situations involving measurement.
- Analyze precision, accuracy, and approximate error in measurement situations.
- Understand the differences among various kinds of studies and which types of inferences can legitimately be drawn from each.
- Know the characteristics of well-designed studies, including the role of randomization in surveys and experiments.
- Compute basic statistics and understand the distinction between a statistic and a parameter.
- Use simulations to explore the variability of sample statistics from a known population and to construct sampling distributions.
- Understand how sample statistics reflect the values of population parameters and use sampling distributions as the basis for informal inference.
- Evaluate published reports that are based on data by examining the design of the study, the appropriateness of the data analysis, and the validity of conclusions.
- Understand how basic statistical techniques are used to monitor process characteristics in the workplace.
- Recognize and apply mathematics in contexts outside of mathematics.
- Use representations to model and interpret physical, social, and mathematical phenomena.

Science

- Describing change.
- Averages and comparisons.
- Correlation.
- Statistical reasoning.
- Understandings about science and technology.
- Interaction of technology and society.
- Decisions about using technology.
- Population growth.
- Environmental quality.
- Natural and human-induced hazards.
- Science and technology in local, national, and global challenges.
- Science as a human endeavor.
- Influences of social change.
- Social decisions.
- Nature of scientific knowledge.
- Historical perspectives.

English

- *Lab reports*
  Students will link their English writing skills with this course through lab reports. Students should use complete sentences to describe their thinking processes and activities in detail.
- *Documentation*
  Technical data and information is recorded as part of the activities.
- *Essays*
  These should be used as a tool to evaluate whether or not students understand broad concepts and issues in technology. These may be given as individual assignments or could be included as part of a larger group assignment. Teachers should develop grading criteria and inform the students of the criteria before the essay is started.

Chapter 2, Unit 3

Concurrent Engineering and Teamwork

Standards for Technological Literacy Standards Addressed in Unit 3

Unit 3 addresses the following *STL* standards:

- **Standard 9** Students will develop an understanding of engineering design.
- **Standard 15** Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.

Big Idea

Engineering Process

Student Assessment Criteria – Concurrent Engineering

Achievement Level / Sub-concept	Above Target 3	At Target 2	Below Target 1
Design Process	**Thoroughly analyzes** a problem or opportunity situation, explores possibilities, proposes solutions and designs, tests models, prototypes a likely solution, and proposes the best answer.	**Analyzes** a problem or opportunity situation, explores possibilities, proposes solutions and designs, tests models, prototypes a likely solution, and proposes the best answer.	**Analyzes, but with minimal insight,** a problem or opportunity situation, explores possibilities, proposes solutions and designs, tests models, prototypes a likely solution, and proposes the best answer.
Teamwork	**Effectively coordinates** the efforts of **a design team** to systematically address a problem or opportunity situation.	**Contributes effectively as a team member** to the efforts of a design team to systematically address a problem or opportunity situation.	**Functions ineffectively as a team member** in the efforts of a design team to systematically address a problem or opportunity situation.
Organization and Schedule Management	**Effectively coordinates** the efforts of **several** design teams to insure that all elements of a project are coming together on a timely, efficient, and effective schedule.	**Effectively participates** in the efforts of several design teams to insure that all elements of a project are coming together on a timely, efficient, and effective schedule.	**Participates as a member of one** of several design teams to help ensure that all elements of a project come together on a timely, efficient, and effective schedule.
Productivity	**Analytically and thoughtfully assesses** the effectiveness of a design through production processes of a project to determine the extent to which all elements came together efficiently.	**Assesses** the effectiveness of a design through production processes of a project to determine the extent to which all elements came together efficiently.	**Assesses, but with some difficulty,** the effectiveness of a design through production processes of a project to determine the extent to which all elements came together efficiently.

Student Learning Experiences

Airplane in a Box
Precision Directions
Desert Survival
The String and the Ring
Golf Course Development

As a set of learning experiences, the following *STL* content standards and corresponding benchmarks are addressed: Standard 9, Benchmarks I, J, K, and L; and Standard 15, Benchmarks K, L, M, and N. However, if you choose to use only a specific activity, please refer to Appendix B to determine exactly which standards and benchmarks are being addressed by that learning experience. See **Appendix B** for a complete listing of the *STL* content standards.

Acceptable Evidence of Student Understanding

1. Document evidence of daily progress with the use of a lab report or journal.
2. Define the term concurrent engineering.
3. Write clear instructions for a prototype.
4. Create a design based on a set of written instructions.
5. Collaborate with others to rewrite a set of instructions.
6. Define the terms “dictatorship,” “majority rule,” and “consensus.”
7. Participate in group decision making.
8. Problem-solve in a group to complete a group task.
9. Design a concurrent scale model golf course hole.
10. Present information learned about concurrent engineering and teamwork to peers.

Special note: Please keep in mind that criteria must be developed to measure the evidence that students provide in demonstrating their levels of understanding—what are we looking for and how will we know it when we see it? For example, if students are asked to build a model, how will we know if it’s a good one?

When considering achievement levels and helping students to understand how they might improve, it will be necessary to know what we mean by terms such as effectively, efficiently, adequately, creatively, thoughtfully, mostly, clearly, minimally, marginally, correctly, safely, systematically, randomly, logically, thoroughly, introspectively, insightfully, and meaningfully. (See **Appendix D, Acceptable Evidence Glossary**, for definitions.)

Overview

When a project is initiated, a team of professionals is called together to do the planning. The team may include various types of engineers, technicians, draftspersons, etc. A project engineer may coordinate all aspects of the project. This process is concurrent engineering. Webster’s Dictionary describes concurrent engineering as:

1. Happening at the same time as something else.
2. Operating or acting in conjunction with another.
3. Meeting or tending to meet at the same point; convergent.
4. Being in accordance; harmonious.

Concurrent engineering is a systematic approach to the integrated, simultaneous design of products and their related processes, including manufacturing and support. This type of approach is used from the beginning of a project to require the developer of the idea to consider all elements of the product or system, from concept through disposal. Concurrent engineering also includes aspects of quality control, cost, scheduling, and user requirements.
Integrated Product Development (IPD) is a philosophy that meticulously teams functional disciplines to integrate, and simultaneously meshes all prescribed processes to produce, an effective and efficient product that satisfies the customer’s needs.

Benefits of CE and IPD include 30% to 70% less development time, 65% to 90% fewer engineering changes, 20% to 90% less time to market, 200% to 600% higher quality, and 20% to 110% higher white collar productivity. (As reported by the National Institute of Standards & Technology, Thomas Group Inc., and Institute for Defense Analyses in *Business Week* April 30, 1990).

In many traditional classrooms, students are assigned to seats sitting in rows and are discouraged from talking with each other. Society then expects them to communicate and interact with people all day long while working. This curriculum encourages students to communicate with each other while sharing ideas.

Many companies use teamwork as the basis for how they do business. For example, a company might offer incentives or bonuses to teams of individuals that worked in cells to produce a defined number of products. If that team were to exceed the projected number of working/standard units to be produced during a shift, its members would receive compensation (money, stock, awards, etc). These employees then learn to work together because they have incentives and not just a given paycheck at the end of the week. It also can be used as a great opportunity for employees to provide feedback or improvements in a system. They work in the environment every day and should be provided an opportunity to improve systems and the way things are done—and rewarded when their ideas are implemented or increase production. Webster's Dictionary defines teamwork as: cooperative effort by the members of a group or team to achieve a common goal.

Teacher Preparation

The suggested learning activities in this unit are teamwork-oriented. Teachers should inform students about strategies and tools to effectively work in teams. Conflict resolution may be another topic that can be covered in detail before starting any case study or activity.

Unit 3 Content Outline

I. Concurrent engineering and teamwork
    A. Definition
        1. Synchronization or synergism of team members, groups of people, or company departments to ensure that every person involved knows and understands the task at hand, the parameters that have to be met, and the set of skills that will be employed to solve the problem.
        2. Integrated Product Development (IPD) is a philosophy that systematically employs a teaming of functional disciplines to integrate and concurrently apply all necessary processes to produce an effective and efficient product that satisfies the customer's needs
    B. Initiated before brainstorming
        1. Should be, but not limited to this timeframe
    C. Multidisciplinary teams
    D. Communication
        1. Development
        2. Manufacturing
        3. Marketing
        4. Distribution
    E. Techniques, procedures, goals
    F. Compromise
    G. Agreement
    H. Implementation

II. Influence on design comes from personal characteristics
    A. Having multiple persons on a design team helps generate solutions
        1. Factors
            a. Creativity
            b. Resourcefulness
            c. Ability to visualize and think abstractly

III. Conflicts often occur between group members
    A. Opinions
    B. Backgrounds
    C. Experiences
    D. Personalities

Suggested Learning Activities

Airplane in a Box

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *1 day*

Teacher Preparation

This case study will take one classroom day to complete. Spend the first portion of the class period talking about concurrent engineering and teamwork and then introduce the case study. This should only take about ten to fifteen minutes after you have covered the information at the beginning of class.

This case study provides students an example of what happens when teamwork and concurrent engineering techniques are not used. DO NOT tell them how the objects they are designing are going to be used. Split the class in half and put students in two different rooms (or one half in the hallway). Assign an object to each group and give them 5-8 minutes to complete the build (they all build their own). More than likely you will want the students who build the airplane to be within your supervision at all times. However, students who are building the boxes tend to need a bit more time and always need your help. If they need a few pieces of tape, make those available in the same location as the scissors.

After the time expires, have the students from outside the classroom come into the room and stand next to one of the students from the other group. NO TALKING! You should then remind them that this day's purpose was teaching about concurrent engineering. Then ask them (without altering either object) to put the airplane in the box. Most teams of students will not be able to do this, though a few may try jamming it in or folding up the airplane to make it fit. Very few times will a student be able to actually fit the airplane into the box.

Ask the students these questions:

1. Would you have designed the airplane differently if you knew it would have to fit into a box made from a sheet of copy paper?
2. Would you have designed the box differently if you knew a paper airplane made from a piece of copy paper had to fit into it?

Teachers will need to provide students with the following:

- Copy paper – 1 per student in both groups
- Scissors – box constructors only
- Tape – box constructors only

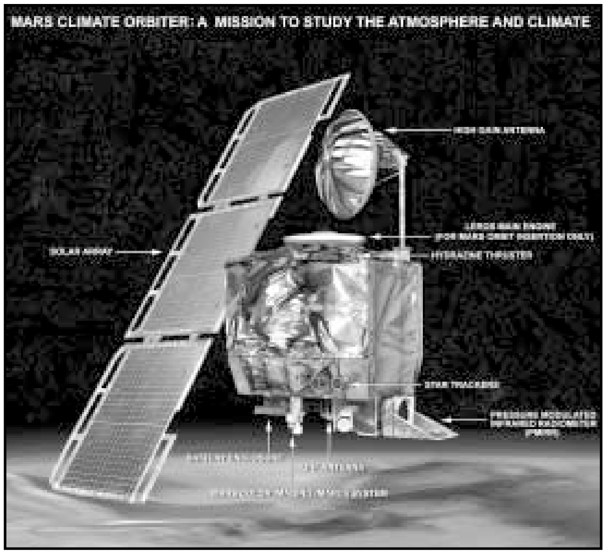
Case Study

When a company designs something for production, many times that company is not the one that actually manufactures it. Everyone who plays a part in the development and completion of a particular product must be on the same page in order to achieve maximum results. If one team player makes a mistake or does not understand the procedures that are being used within a project, the end result may be total failure. For example, NASA lost an unmanned module that was trying to land on Mars. The failure was attributed to something basic, something that may affect the way college students study science and engineering in the future. The first mistake was that the satellite was composed of materials that were not sufficiently resistant to heat. There were also issues with the weight distribution being uneven in the satellite, causing it to wobble excessively. But the major blunder was that the trajectory calculations were made using American units (pounds of force) by the subcontractor, Martin Marietta, whereas NASA assumed that they were metric units (Newtons).

You can see from this example that if one small piece of a project is overlooked or assumed, it can have catastrophic results.

In this case study you will build *one* of the following out of one sheet of copy paper:

1. A paper airplane
2. A box



Mars Climate Orbiter image created by Corby Waste.

Your instructor will place you in two different rooms, or one group in the hallway and one in the classroom, to build your objects. If you are assigned to the paper airplane, please do not "test" your creation, as this is not its intent.

Assessment

This case study is simple to do and will take up minimal time within your classroom. It is suggested that students receive a pass/fail grade or a participation grade for this assignment, as it is a demonstrative task that may not warrant point values to be assigned to it. Teachers may want to reward any group that actually can put the airplane in the box with extra credit or additional credit within the scope of the class.

Resources

http://mars.jpl.nasa.gov/msp98/news/mco991110.html – NASA's report on the response to the loss of the Mars Climate Orbiter and the initial findings of the mission failure investigation board.

Precision Directions

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *2-3 days*

Teacher Preparation

This case study will take two to three classroom days to complete.

Case Study

Oral and written communications are very important between teams of people working on projects. It is evident that mistakes or misrepresentations can cause the end product to be something different than intended. It is for this reason that any written communications should be done with neat and clear handwriting. Examples range from criminals escaping jail time because of bad penmanship by police officers to patients who receive the wrong prescriptions from pharmacists because of a doctor's poor handwriting. It is clear that when communicating with others, precision and clarity are paramount.

Part A

You are responsible for developing a paper airplane prototype. Brainstorm a design for your prototype and write instructions so that someone else can replicate your design. Use one piece of paper to make your prototype airplane and one piece of paper to write the instructions on. Make sure that both pieces of paper have your name on them. Return your instruction sheet to your teacher and safely store your prototype plane until asked to present it.

Part B

Your instructor will provide you with a sheet of paper and a set of instructions from one of your classmates. Follow the instructions exactly to produce a paper airplane. After you complete the paper airplane from the given instructions, your teacher will ask you to find the person who originally designed the plane and wrote the instructions. Compare the model you created from the instructions to the original prototype.

Answer the following questions:

1. Does the model made from the instructions look exactly like the original prototype? If not, what are the differences?

2. What questions did you have about the directions written to make the model?
3. What could the person who wrote the directions have done to make it easier to make the model?
4. Rewrite the instructions for the original prototype with the creator.

Former President Ronald Reagan launches a paper airplane made from White House stationary from the balcony of his Los Angeles hotel room.

Photo published with permission of the Reagan Library.

Assessment

Precision Directions Rubric

Category	Exemplary 5-4	Accomplished 3	Developing 2	Beginning 1	Score
Part A - Directions	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demon-strating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	
Part A - Model	The model and brainstorming sketches are complete, with detail and relevant materials and labels.	The model and brainstorming sketches are complete, using relevant materials and labels.	The model and brainstorming sketches are complete, using relevant materials.	The model and brainstorming sketches are incomplete, but use relevant materials.	
Part B Questions	All questions are accounted for and have valid, clear answers.	Most questions are accounted for and have valid, clear answers.	Most questions are accounted for.	Most questions are accounted for, but answers may not be valid or clear and defined.	
Part B Recreation	Presents easy-to-follow information that is logical and adequately detailed.	Most of the phrases are understandable; some lack detail or are confusing.	Some of the phrases are understandable; most are confusing and lack detail.	Most of the phrases are missing or mis-ordered, or definitions are all confusing.	
Part B - Rewrite	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demon-strating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	

Resources

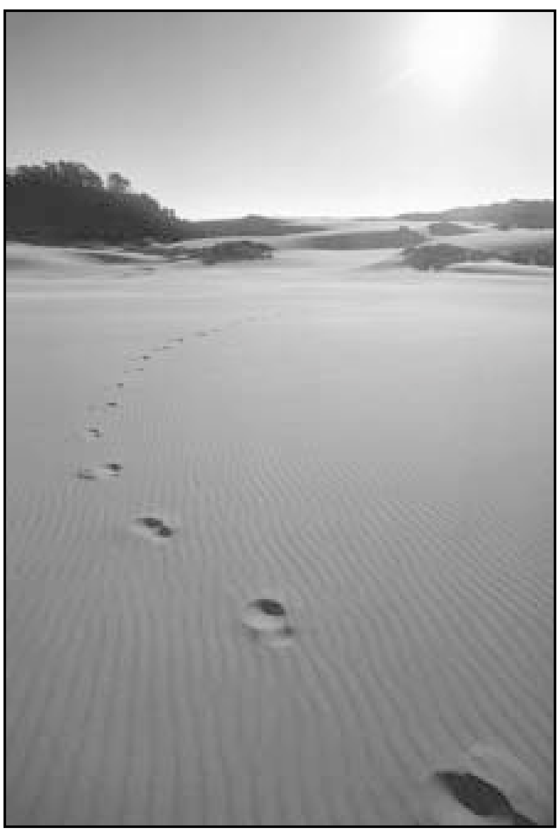
www.reagan.utexas.edu – The image used in this case study is courtesy of The Ronald Reagan Library, 40 Presidential Drive, Simi Valley, CA 93065.

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *1-2 days*

Teacher Preparation

This case study will take one to two classroom days to complete. Instructors should discuss what teamwork is, as well as strategies to use when working in teams. It is also helpful to discuss three different ways that teams can make decisions. They are:

1. *Dictatorship*: One member dominates and makes all the decisions. It does not provide for participation between group members. It requires very little of group members in terms of communication skills, creative thinking, or open-mindedness.
2. *Majority Rule*: All members of the group vote, and the majority wins. It provides for the active participation of all group members. It requires a great deal from the group members in terms of communication skills, but it may not encourage creative thinking or open-mindedness.
3. *Consensus*: All members of the group find a proposal acceptable enough that all members can support it; no member opposes it. It requires time, participation by all, communication, creative thinking, and open-mindedness. It is not a unanimous decision.



Case Study

A planeload of Uruguayan rugby players crashed into the Andes Mountains in 1972. Some survived, but not all. As the days passed, they slowly realized that the tragedy wasn't over, and their lives depended on their ability to adapt and survive with what little they had. This is a true story. There have been books and articles published, and movies made of the ordeal. The books and the movies tell the story, but when it is broken down into its simplest form, it is about teamwork and problem solving. They had very different troubles to unravel than the average person living in civilization—they had to figure out how to survive. For 72 days, those who survived the crash had to design their day with the next in mind. They had to work together and work through their differences. Many engineering teams will have differences; it is human nature to fight for your own opinions and "stick to your guns."

However, for a project to survive, or a group of people to survive, certain compromises always have to be made. It is how a team, engineering or otherwise, goes though this process that is the valuable lesson.

> *The key elements in the art of working together are how to deal with change, how to deal with conflict, and how to reach our potential...the needs of the team are best met when we meet the needs of individual persons.*
> *Max DePree*

You will be working individually first and then together in a team designated by your instructor to complete this case study. The situation is as follows:

It is approximately 10 AM in mid-August and you have just crash-landed in the Sonora Desert in the southwestern United States. The light, twin-engine plane containing the bodies of the pilot and co-pilot has completely burned. Only the airframe remains. None of the rest of you has been injured.

The pilot was unable to notify anyone of your position before the crash. However, he had indicated before impact that you were 70 miles from a mining camp, which is the nearest known habitation, and that you were approximately 65 miles off the course that was filed in your VFR Flight Plan.

The immediate area is quite flat and, except for occasional barrel and saguaro cacti, appears to be rather barren. The last weather report indicated that the temperature would reach 100 degrees that day, which means that the temperature at ground level will be 130 degrees. You are dressed in lightweight clothing—short sleeved shirts, pants, socks, and street shoes. Everyone has a handkerchief. Collectively, your pockets contain $2.83 in change, $85.00 in bills, a pack of cigarettes, and a ballpoint pen.

Before the plane caught fire, your group was able to salvage the fifteen items listed. Your team's task is to rank these items in the order of their importance to your survival, starting with a "1" as the most important to "15" as the least important.

Your team may assume:

1. The number of survivors is the same as the number on your class team.
2. You are the actual people in the situation.
3. The team must stay together.
4. All items are in good condition.

Part A
Each member of the team is to individually rank each item. DO NOT discuss the situation or the survival items until each member has finished the individual ranking. You will have 15 minutes to complete the reading and the rankings.

Part B
After everyone has finished the individual ranking, rank in order the 15 items as a team. Once discussion begins, do not change your individual ranking. Your team will have 15 minutes to work on the collective rankings.

Add up all the individual scores in step 4 and divide the total by the number of people in your group. This is your team score. Compare that number with the total number in step 5. Was your group ranking close to the team score?

Assessment

Students will be asked to answer a series of questions based on their experience in the case study. The

ITEMS	STEP 1 Individual Rank	STEP 2 Team Rank	STEP 3 Expert Rank	STEP 4 Difference Between 1 & 3	STEP 5 Difference Between 2 & 3
Flashlight (4 battery size)					
Jackknife					
Sectional air map of the area					
Plastic raincoat (large)					
Magnetic compass					
Compress kit with gauze					
.45 caliber pistol (loaded)					
Parachute (red & white)					
Bottle of salt tablets (1000 tablets)					
1 quart of water per person					
Book entitled, *Edible Animals of the Desert*					
Pair of sunglasses per person					
2 quarts of 180 proof vodka					
1 top coat per person					
Cosmetic mirror					
			TOTALS		

Total Quality Curriculum, from which this was adapted, has a series of class discussions and additional teaching materials to further this experience. It is suggested that the teacher obtain these materials to complement the activity. Below are the questions the students should answer. This one- or two-day activity would warrant points given for the individual rankings, the team rankings, and the questions. Point values for each section should be relative to the amount of work for each section. For example: 10 points for the individual ranking, 15 points for the group ranking, and 20 points for the questions.

Here are the student questions:

1. Did a group leader emerge?
2. How were decisions reached?
   a. Dictatorship
   b. Majority Rule
   c. Consensus
   d. Something else
3. Describe the styles of leadership the leader used.
4. Did disagreements occur?
5. How were disagreements handled?
6. Was everyone allowed to contribute?
7. Was there conflict?
8. How was the conflict resolved?
9. Did everyone seem to feel all right about how the conflict was resolved?
10. How did the team members feel about the decision that was reached?

Resources

www.skillsusa.org/tqcpage.html
The Total Quality Curriculum (TQC) was designed to help meet the needs of American business and industry. These needs were brought about because of changes in the global economy—the American workforce can no longer remain competitive using old methods. The Total Quality Curriculum enhances SkillsUSA's Quality at Work movement by preparing students in the classroom for the world of work.

The Desert Survival Situation activity was adapted for use in the Total Quality Curriculum by permission from J.C. Lafferty, Ph.D., Human Synergenics, Inc., 1987, San Diego, CA.

The String and the Ring

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *1-2 days*

Teacher Preparation

This case study will take one or two classroom days to complete. Teachers should have the proper setup complete before students enter the room on the first day. Determine how many teams there will be and the number of students on each team. The number of team members will dictate the number of strings attached to the 1 ½" steel ring. Set the ring and the string up in an area that is large enough for the team to move around (this should be outside if weather permits). The 1" PVC piping and the ball should also be in place prior to class.

Teachers may vary the activity by placing objects in the path of the objective, or changing the size and/or the weight of the ball. Keep in mind that smaller objects can fit more easily into the larger rings, so the ring size may have to be adjusted as well. Place the objective 1" PVC pipe no closer than 10 feet from the origin spot. Be creative, and put your own "spin" on this event.

Teachers will need to obtain string in ten-foot lengths tied to a 1 ½" steel ring. Two 10" sections of 1" diameter PVC piping need to be purchased and cut to their proper length. Usually PVC comes in lengths of 8'-10'. String and the ring can be purchased at the local hardware store at minimal prices.

Case Study

When a person is a part of a team, he or she needs to learn to trust each member of that team to do his/her job. The unit works in harmony, with each component contributing to the cause. For example, if you were to join a team of orange farmers in Florida, and you were originally from Wisconsin and owned an apple orchard, would there be some things that may stand in the way of your success in the orange business? More than likely, someone who has teamwork experience in one field can make the transition to another. This example can be used in many different fields and provides the basic foundation for a teamwork philosophy: "Whatever you have done, whomever you have known, and however you have done things in the past, draw from those experiences to advance the team and complete your objective. In short, get it done." (Gomez, 2003)

In this case study, you will be part of a team of students that has to accomplish a simple task. You will move an ordinary tennis ball from the top of a 1" section of PVC pipe that is 10" off the ground. A set of strings will be attached to a 1.5" steel ring that is placed around the base of the PVC tube. Your team of students will have to work together to pick the tennis ball off the initial tube and transfer it to another tube that is at least 20' away. Team members may hold on to the end of the string only. If the tennis ball ever falls from the center ring, your team must place it back on the initial pipe and start over. One person should be designated to take notes on the different ideas your team comes up with, the mistakes made, and the ways your team works together to accomplish the task. A short presentation to the entire class will then be completed as a debriefing.

Assessment

It is suggested that this activity be self-assessed. Students can reflect on what kinds of things happened while the team went through the activity. Students should answer the following questions:

1. What made this so difficult?
2. How did you compensate as a team? As an individual?
3. Rate your personal communication effectiveness on a scale of one to ten, ten being the best communicator and one being the worst. Why?
4. Was there one leader or more?
5. Was anyone excluded?
6. How many tries did it take to complete the task?

Resources

The heart of this case study has been used by many corporations, ropes courses, and youth groups as a team-building activity. It has many different variations to it, and most are applicable to the classroom.

Golf Course Development

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *10-14 days*

Teacher Preparation

This case study will take 10 to 14 classroom days to complete. Instructors should prepare for this case study by visiting professor Paul Hsu's and Mr. Tony S. Ristola's Web sites (located in the resources section). After looking over the Web sites and samples of Professor Hsu's students' work, it is suggested that you review the courses that Mr. Ristola has designed and constructed.

Your students will either love or hate the game of golf and the facilities used to play the game. This case study's objective is not to debate the positives or negatives of golf courses, although this may become a small portion of the initial phase of the project. Field trips or walks to your local course may be of interest, as some students have never visited one.

Supplies are relatively easy to assemble for this case study. Make sure you have enough construction paper available in the correct colors (see case study parameters). Foam core or extruded polystyrene foam from your hardware store will be essential in the buildup from grade of each group's hole. Remember that concurrent engineering is the theme in this case study, so students have to match up their hole with the previous one as well as the one after. Three-dimensional vegetation is encouraged, but must be to scale. A good base to set all the model holes on is 3" extruded polystyrene sheets. Plywood or even a tabletop could be solutions also. Make that decision based on the resources and space you have available. Scale is a critical portion of the case study and should remain at 1”=60’ for the model and 1”=100’ for the drawings. Obtain at least one engineering scale for each group, so they are all on the same page. CAD drawings are encouraged, and 3-D animations help for presentations.

It is suggested you assign holes to groups for an 18-hole regulation course (70-72 Rating, 6200-6500 yards or 6700 yards)

- 4 holes up to 250 yd
- 10 holes@ 251-470
- 4 holes 471-550≥
- Championship yards ≤120-225 285-470

Case Study

Every day our pursuits take us past areas that we may never notice or utilize, although other people may use them to relax and enjoy their free time. These areas may be a city park, a neighborhood green space, a wooded area of town, or even a golf course. The environment is something we all should respect a little more each day. This case study is intended to provide perspective into the area of sustainable development.

Sustainable development is defined in Caring for the Earth (IUCN, UNEP, WWF, 1991) as “improving the quality of human life while living within the carrying capacity of supporting ecosystems.”

The teams should pay strict attention to the surrounding environment, and if a specific site is determined, care should be taken to sustain as much of the existing nature as possible.

In this case study, teams of three students will design one hole of an 18-hole golf course. All vegetation, course-required elements, and safety corridors must be strictly adhered to. All teams must design with the specified scale for the case study. Each team must establish a working relationship with the teams that are behind them and in front of them in the course construction. For example, hole three’s team must communicate with hole two’s team so that there is a concurrent design from two to three. The same has to be done in relation to team four’s hole. It is critical to the development of the entire project that each team not only have a working relationship within their group, but also with other teams developing solutions.

Formulate criteria for site (hole) evaluation:

- List all on-site and off-site natural and cultural factors that influence the citing of lodge, lake, sport facilities, western town, golf course development, and access roads. Make efforts to understand the prevailing winds, slope orientation and percentage, views, solar orientation, etc. Think about them in terms of their potentials and constraints for site development.

List the square feet or length/width requirements for each site (hole) development. Develop this information into bubbles of approximate sizes.

- Lay these bubbles onto their approximate location on site and discuss their potential and constraints. Mark each bubble’s desired finished elevation for future grading reference.

Holistically, route the vehicular circulation, walking trails, and major drainage ways.

Required elements:

1. Final drawing of your team's specified hole to scale 1"=100'.
2. Title block and credit information.
3. Written summary and labels on drawing.
4. Color-coded paper model of your team's hole (scale 1"=60').
   - Should be three dimensional.
   - Should match up correctly with hole previous and hole after.
   - Green for tee boxes and putting greens.
   - Red, blue, and white for designated tees.
     - Red for farthest forward.
     - White for next set back.
     - Blue for next set back.
     - Black for professional distance.
   - Black for hole location.
   - Light blue for water hazards.
   - Light brown for sand hazards.
   - Brown/grey for rock hazards.
5. Vegetation as needed for design (use 3-D objects to scale).
6. Presentation of your model to peers.

Assessment

Golf Course Development Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Research	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demonstrating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	
Scale Model	The model and sketches are complete, with detail and relevant materials and labels.	The model and sketches are complete, using relevant materials and labels.	The model and sketches are complete, using relevant materials.	The model and sketches are incomplete, but use relevant materials.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disordered, or confusing.	
Final Drawing	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawings include relevant materials, with missing information or dimensions.	The drawings are incomplete, but an attempt was made.	
Concurrency	The hole designed matches up precisely with the hole previous to and after its placement.	The hole designed matches up with the hole previous to and after its placement, with some variances.	The hole designed does not match up with one of the holes previous to or after its placement.	The hole designed does not match up with the hole previous to and after its placement, but can be modified to comply.	

Resources

www.glpbooks.com – Great Lakes Press Web site.

www.agolfarchitect.com – Tony S. Ristola is a fourteen-year PGA member, former tournament and teaching professional. Before designing and supervising the construction of his own projects, he was involved in building courses for some of the most recognized names in the industry. Tony's participation and his Web site have been a critical part of the development of this case study.

http://home.okstate.edu/homepages.nsf/toc/HsuHome – Professor Paul Hsu was born in Taiwan, ROC and was naturalized as a United States Citizen in 1985. Professor Hsu has contributed elements from his golf course development section within his landscape architecture program. His participation with this case study brings together the artistic and technical aspects of course development. He received a Bachelor of Science degree in Geography from National Taiwan University, Master of Landscape Architecture degree from Cornell University, and is a Ph.D. candidate in Spatial Science and Engineering at the University of Maine.

Carpenter, Jot. Ed. (1976). In Beazley, Mitchell, International Limited, Ed. *Handbook of Landscape Architectural Construction*. Washington, DC: Landscape Architecture Foundation. American Society of Landscape Architects. Pp. 459-469.

The New World Atlas of Golf. (1989). London: Mitchell Beazley Publishers.

Jarrett, Albert. (1984). *Golf Course & Grounds – Irrigation and drainage*. Englewood Cliffs, NJ: Prentice Hall, Inc. ISBN 0-8359-2563-3.

Doark, Tom. (1992). *The Anatomy of A Golf Course*., New York, NY: Lyons & Burford. ISBN 1-55821-146-2.

Golf Course Development and Real Estate. (1994). Washington, DC: ULI. ISBN: 0-87420-762-2.

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Academic Connections – Unit 3

Mathematics

- Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more complicated cases.
- Judge the reasonableness of numerical computations and their results.
- Approximate and interpret rates of change from graphical and numerical data.
- Use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest such as art and architecture.
- Make decisions about units and scales that are appropriate for problem situations involving measurement.
- Analyze precision, accuracy, and approximate error in measurement situations.
- Understand and use formulas for area, surface area, and volume of geometric figures, including cones, spheres, and cylinders.
- Apply informal concepts of successive approximation, upper and lower bounds, and limit in measurement situations.
- Evaluate published reports that are based on data by examining the design of the study, the appropriateness of the data analysis, and the validity of conclusions.
- Understand how basic statistical techniques are used to monitor process characteristics in the workplace.
- Solve problems that arise in mathematics and in other contexts.
- Apply and adapt a variety of appropriate strategies to solve problems.
- Recognize and apply mathematics in contexts outside of mathematics.
- Use representations to model and interpret physical, social, and mathematical phenomena.

Science

- Identify questions and concepts that guide scientific investigations.
- Design and conduct scientific investigations.
- Recognize and analyze alternative explanations and models.
- Evidence and reasoning in inquiry.
- Describing change.
- Design constraints.
- Designed systems.
- Identify a problem or design an opportunity.
- Propose designs and choose between alternative solutions.
- Implement a proposed solution.
- Evaluate the solution and its consequences.
- Communicate the problem, process, and solution.

English

- *Lab reports*
  Students will link their English writing skills with this course through lab reports. The students should use complete sentences to describe their thoughts and activities.
- *Documentation*
  Technical data and information is recorded as part of the activities.
- *Essays*
  These should be used as a tool to summarize and synthesize research. They may be given as individual assignments or could be included as part of a larger assignment. Teachers should develop grading criteria and inform the students before the essay is started.

Chapter 2, Unit 4

Modeling and Problem Solving

***Standards for Technological Literacy* Standards Addressed in Unit 4**

Unit 4 addresses the following *STL* standards:

- **Standard 1** Students will develop an understanding of the characteristics and scope of technology.
- **Standard 8** Students will develop an understanding of the attributes of design.
- **Standard 11** Students will develop the abilities to apply the design process.
- **Standard 16** Students will develop an understanding of and be able to select and use energy and power technologies.

Big Ideas

Modeling and Problem Solving

Student Assessment Criteria – Modeling

Achievement Level / Sub-concept	Above Target 3	At Target 2	Below Target 1
Thinking Process	**Conceptualizes** the breadth and depth of a project, **creatively visualizes** the possibilities and potential problems, applies **various** idea-generating processes (including modeling), gathers data, tests solutions, and **effectively presents** plausible answers.	**Sees with some understanding,** the breadth and depth of a project, **visualizes some** possibilities and potential problems, applies **several** idea-generating processes, gathers data, tests solutions, and **presents** plausible answers.	**Sees but with little understanding**, the breadth and depth of a project, **focuses on a** possibility with little consideration for potential problems, applies a **few** idea-generating processes, gathers **little** data, tests solutions, and **presents** plausible answers **with minimal effectiveness**.
Types of Models	**Makes creative and extensive use of** sketches, drawings, and scenarios **along with** computer, mathematical, and physical models to generate and test **a variety** of ideas.	**Uses** sketches, drawings, and scenarios **along with** computer, mathematical, and physical models to generate and test ideas.	**Makes little use of** sketches, drawings, and scenarios **or** computer, mathematical, and physical models to generate and test ideas. **Tends to lock in on the first idea without exploring other possibilities.**
Communication Process	**Creatively and effectively conceptualizes and presents** ideas using **a variety** of presentation media and techniques, including models.	**Effectively conceptualizes and presents** ideas using **a variety** of presentation media and techniques, including models.	**Presents ideas with some degree of effectiveness,** using **a limited** amount of media and techniques with **little use** of models.

Student Assessment Criteria – Problem Solving

Achievement Level / Sub-concept	Above Target 3	At Target 2	Below Target 1
Defining the Challenge	The challenge is **very clear, specific, and focused.**	The challenge is **somewhat specific and focused.**	The challenges **need to be more clearly stated and focused**.
Proposing Solutions	Sketches, drawings, and descriptions suggest a **wide range of possibilities**.	Sketches, drawings, and descriptions show **some "out-of-the-box" possibilities.**	Proposals suggest a **limited number of possibilities.**
Testing Possibilities	**Effective** drawings, descriptions, and prototypes of several possibilities.	**Somewhat effective** drawings and prototypes of a few possibilities.	**Minimally effective** drawings and one prototype of a possible solution.
Applying the Design	An **effective** drawing, model, portfolio, and presentation of a creative solution.	A **reasonably effective** drawing, model, portfolio, and presentation of a somewhat creative solution.	A drawing, model, portfolio, and presentation of a solution.

Student Learning Experiences

Destructive Testing and Mathematical Modeling
Putting and Plotting
The Janitor's Dilemma
Ping Pong Launch
Scrambler Vehicle

As a set of learning experiences, the following *STL* content standards and corresponding benchmarks are addressed: Standard 1, Benchmarks J, K, L, and M; Standard 8, Benchmarks H, I, J, and K; Standard 11, Benchmarks M, N, O, P, Q, and R; and Standard 16, Benchmarks J, K, L, M, and N. However, if you choose to use only a specific activity, please refer to Appendix B to determine exactly which standards and benchmarks are being addressed by that learning experience. See **Appendix B** for a complete listing of the *STL* content standards.

Acceptable Evidence of Student Understanding

1. Document evidence of daily progress with the use of a daily lab report or journal.
2. Define the terms descriptive, functional, mathematical, and scale modeling.
3. Use brainstorming techniques to generate ideas.
4. Use proper problem-solving techniques in their order to solve case studies.
5. Define the term "destructive testing."
6. Chart data, using spreadheet software or graph paper.
7. Compare data sets and provide an evaluation of the results.
8. Calculate heat loss and combined thermal conductivity.
9. Define the terms R-Value, U Factor, and BTUs.
10. Provide accurate research to document a prototype's evolution and solution.
11. Develop prototype solutions based on the problem-solving and modeling processes.
12. Test prototypes and redesign them according to the parameters set and the results of testing.

Special note: Please keep in mind that criteria must be developed to measure the evidence that students provide in demonstrating their levels of understanding—what are we looking for and how will we know it when we see it? For example, if students are asked to build a model, how will we know if it's a good one?

When considering achievement levels and helping students to understand how they might improve, it will be necessary to know what we mean by terms such as effectively, efficiently, adequately, creatively, thoughtfully, mostly, clearly, minimally, marginally, correctly, safely, systematically, randomly, logically, thoroughly, introspectively, insightfully, and meaningfully. (See **Appendix D, Acceptable Evidence Glossary**, for definitions.)

Overview

Modeling is a method of illustrating a solution to a practical problem. Students need to understand that engineers and technicians can use different forms of modeling to assess and develop a product. The types of modeling are descriptive, functional, mathematical, and scale modeling.

Descriptive modeling may include diagrams, graphs, flowcharts, and block diagrams. Verbal modeling describes the behavior of systems. Mathematical modeling in the form of equations shows the relationship between variables in the systems. Scale models may also be included in descriptive modeling.

Functional modeling may include computer simulations that support investigations of system behaviors or physical models of real systems with moving parts.

Mathematical Modeling may include heat-flow formulas, population growth, a spring mass system, or a falling rock. Mathematical models are used to provide evidence and to prove the validity of a solution.

Scale modeling – CAD drawings using wire-frame modeling, surface modeling, and solid modeling. These can be of the two-dimensional or three-dimensional types. Physical models that accurately depict the object of focus can also be developed. It is to be noted that a scale model can also be a functional model.

All students should start on a simple case study introducing them to brainstorming and thumbnail sketching, problem-solving techniques that they may or may not know. Good brainstorming means getting everything down on paper in thumbnail sketches—small drawings that try to capture the thought process. Ideas not expressed in a communicable medium will exist in the designers' minds alone and never come to reality. When brainstorming, sit and focus on generating ideas for 20 minutes at a time, no more. Most likely, 75% of ideas generated in these sessions are going to be sub-par, but that's normal. Therefore, only one out of four ideas will be developed into a final solution.

During the final development stages of the solution, pay close attention to the designs that were among those that you thought would never work. Pieces of these designs may become parts of the final design. After developing several possible final solutions on paper, pick one to build and test as a prototype.

Run the prototype through several tests that will tell whether or not the design will work or is flawed. When a prototype fails, a designer has to go back to the "drawing board," or the "sub par" ideas generated during the thumbnail sketch time. Look at all of the ideas that were originally sketched to try to develop a new design for the solution to the problem. This method may involve taking many different parts and systems out of all of the thumbnail sketches and grouping them together to produce a design. Every subsequent design that is developed should be tested just as thoroughly as, if not more thoroughly than, the first prototype.

When faced with a problem to be resolved, engineers and technicians must proceed through a series of problem-solving steps. They include:

- Recognition of need – Products created are a direct response to specific needs and wants of society. This statement is in a pure scenario; marketing efforts of large companies can create a need.
- Definition of the problem – All of the specifications that affect the design of the product must be clearly stated. This should be clear and concise, with details of the specific problem. Time, materials, and available equipment should be included in the description. Social and environmental considerations should also be stated in this definition, along with the definition of the environment in which the solution is to be used.
- Analysis of the problem – Brainstorming must take place to formulate possible solutions. Multiple solutions should be generated through the use of thumbnail sketching. These solutions should never be discarded, as sometimes when a final design fails these initial ideas may have portions of a solution within them.
- Selection of a solution – Teams have to identify workable solutions from their preliminary ideas. Details and annotated sketches are then developed to further define the ideas. Any graphical analysis or finite element analysis should be completed at this point.

Solutions that make it to this point should then be compared to each other again and refined into their final form. Design solutions then have to be narrowed in order to choose an optimal solution.

- Development and Implementation – Detailed documentation of the solution selected is required. Working drawings of every component of the solution should be done at this time. Components required for the construction are obtained to complete the construction of a prototype.

- Evaluations and testing – An analysis of the prototype is done to determine whether the specifications are met. The team can complete this, or the prototype can be sent to an independent lab, a selection of companies or people, or a test market for evaluation.

- Re-design – Modifications should be made to the prototype based on the evaluation and testing phase. The process involves reassessing the design specifications to determine if they are a correct fit. Modifications to the solution should then be implemented, and all the drawings and prototypes should be updated to reflect the changes made. It is possible that a new prototype will have to be made rather than modifying the earlier prototypes for aesthetics and functionality, or based on the wants or needs of the team.

Teacher Preparation

The suggested learning activities in this unit are teamwork-oriented; teachers should inform students about strategies and tools to effectively work in teams. Conflict resolution may be another topic that can be covered in detail before starting any case study or activity.

Unit 4 Content Outline

I. Modeling
  A. Descriptive modeling
    1. Diagrams
      a. Cycle – A diagram that is used to show a process with a continuous cycle
      b. Target – A diagram that is used to show steps toward a goal
      c. Radial –A diagram that is used to show relationships of elements to a core element
      d. Venn – A diagram that is used to show areas of overlap between and among elements
      e. Pyramid – A diagram that is used to show foundation-based relationships
    2. Used to
      a. Illustrate various conceptual material
      b. Enliven documents
    3. Graphs
      a. Visually appealing; easy for users to see
        1.) Comparisons
        2.) Patterns
        3.) Trends in data
    4. Flow charts
      a. Document procedures
      b. Analyze processes
      c. Indicate work or information flow
      d. Track cost and efficiency
    5. Block diagrams
      a. Provides shapes to
        1.) Brainstorm
        2.) Plan
        3.) Communicate
    6. Verbal modeling
      a. Description with words
    7. Mathematical modeling
    8. Geoinformatics
      a. e.g. surveying, error theory, Global Position Systems (GPS), photogrammetry, image analysis, Geographical Information Systems (GIS)
    9. Image Processing & Computer Graphics
      a. e.g. biomedical imaging, industrial vision, material science, remote sensing, scientific visualization, and virtual reality
    10. Intelligent Signal Processing
      a. e.g. theory and methods for machine learning/adaptive signal processing, neuroimaging, biomedical signal processing, monitor systems, multimedia, humanitarian demeaning
    11. Mathematical Physics
      a. e.g. boundary value problems, vehicle dynamics, Josephson junctions, nonlinear optics, molecular and biomolecular dynamics
    12. Numerical Analysis
      a. e.g. optimization, simulation and inversion, numerical linear algebra, parallel algorithms, partial differential equations, scientific computing

13. Operations Research
    a. e.g. logistics, transport optimization, vehicle routing, production and inventory planning, timetabling and crew scheduling
14. Statistics
    a. e.g. environmental statistics, statistical design and analysis of experiments, time series analysis, stochastic control theory, multivariate analysis and classification, stochastic processes
15. Scale models
    a. A small object that represents in detail another, often larger object.
    b. A preliminary work or construction that serves as a plan from which a final product is to be made: a clay model ready for casting.
    c. Such a work or construction used in testing or perfecting a final product: a test model of a solar-powered vehicle.

B. Functional modeling
   1. Computer simulations
      a. 3-D solid modeling
      b. 3-D Animation
      c. Finite Element Analysis
   2. Physical models of real systems with moving parts

II. Problem solving
   A. Recognition of need
      1. Direct response to specific needs and wants of society
   B. Definition of the problem
      1. Specifications clearly stated
      2. Constraints clearly stated
   C. Analysis of the problem
      1. Brainstorming to formulate possible solutions
      2. Thumbnail sketches to track ideas
   D. Selection of a solution
      1. Refine preliminary ideas
         a. Identify workable solutions
         b. Develop details/annotated sketches
         c. Graphical analysis of possible solutions
         d. Design analysis
            1.) Compare possible solutions
            2.) Refine alternative solutions
            3.) Narrow design solutions
      2. Chose optimal solution with the aid of a modeling system
   E. Development and Implementation
      1. Detailed documentation of final solution (working drawings)
      2. Components required for the construction
      3. Complete the construction of a prototype
   F. Evaluations and testing
      1. Analysis of the prototype
      2. Are the specifications met?
   G. Re-design
      1. Modifications to the prototype based on the evaluation and testing phase
         a. Reassess design specifications
         b. Implement modifications
         c. Update drawings and prototypes
         d. Prototype new design solution

Suggested Learning Activities

Destructive Testing and Mathematical Modeling

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *2-3 days*

Teacher Preparation

This case study will take three to five classroom days to complete depending on the instruction time needed for spreadsheets. Teachers will have to become familiar with the spreadsheet software; or if software is not available, graph paper and board work is acceptable. Multiple boxes of two different types of paper clips should be obtained for this experiment. Try not to use the huge, thick paper clips, as they are more difficult to bend and more expensive overall.

Case Study

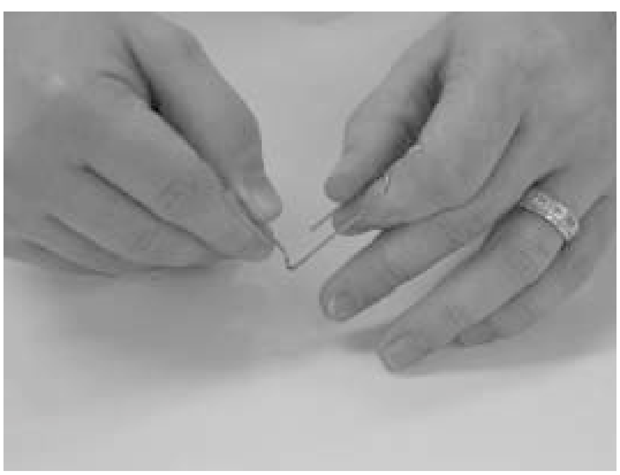
Destructive and nondestructive tests are used for determining the quality of materials. For example, you might test a cookie to see if it is good. In the process, the cookie is consumed. That would be a destructive test. Amniocentesis and ultrasound techniques are used for determining the sex of unborn children. These are nondestructive tests. X-rays were once used to determine the sex of a baby, but it is now believed that high-energy radiation can destroy some living cells. Although X-rays may not completely destroy living things, they are considered partially destructive.

Manufacturers produce a huge number of items daily. In industries where only a few items are produced at a time, it is possible to inspect each item. Even then, some defects may be difficult to detect. Science and technology have developed many different tests to help detect hidden defects. Nondestructive tests are frequently used on expensive items or on items that are difficult to replace.

Since destructive tests usually destroy the item being tested, they are used to test only a few items out of possibly thousands that are produced. A type of mathematics called statistical analysis is then used to determine the probability of finding a defective product. This type of analysis is the job of a quality control (QC) person. Another job done by a QC person might be to attempt to determine the life span of a product. This is frequently accomplished by exposing parts to repeated abuse until the parts fail due to fatigue. Statistical analysis is once again applied in order to make a good estimate of the life of the part. You will use some of these techniques in this experiment.

You and a partner will be using destructive testing to determine the

Step One



Carefully bend the paper clip open.

Step Two

Lay the clip with the small loop on the table and the large loop in your hand.

strength and durability of two different types of paper clips. A good question to ask yourselves is if the paper clips in your experiment are of the same exact material as another group across the room. Could there be slight differences? Will these differences be enough to produce startling results? The procedure for this experiment is below.

1. Lay a paper clip flat on the table or desk top and hold the smaller loop with one hand. Grasp the larger loop with your other hand and bend the clip open one quarter of a turn. Keep the loops flat. You should end with an “L” shape. Note whether the paper clip was easy to open into the “L” shape.
2. Lay the paper clip at the edge of your desk or table so that the small loop is on the table and the large loop is at the edge of the table and projecting up.
3. Grasp the large loop with your dominant hand and hold the small loop firmly right at the table edge with your other hand.
4. Bend the large loop all the way down so that it is pointing down. Count this as one bend. Then bend it back to the position where it is pointing up. Count this as bend 2.
5. Continue to bend the paper clip up and down. Keep count of each bend. Record the number of bends it took to break the paper clip.
6. You and your partner should destructively test ten paper clips. Record your results for each paper clip.
7. Repeat the destructive test with another type of paper clip. Again test ten paper clips until they fail. Record your results.
8. Record your results using a spreadsheet like Microsoft Excel so that you can share data with your classmates. Record the entire class’ data on paper from the chart on the board created by your instructor.
9. Use a spreadsheet to enter all the class data. Make a series of graphs and curves according to your instructor’s directions for each of the two types of paper clips.

Assessment

1. Did you record all observations?
2. What type of testing did you do on the paper clips? List two other materials that would use this type of testing.
3. Why didn’t all of the paper clips give the same results?
4. If you were going to sell and guarantee the type A paper clips, what do you think would be a reasonable guarantee on the number of bends before breaking?
5. If you changed your production techniques, how many tests do you think you would have to make before you could determine a new guarantee? Explain your answer.

Resources

Energy Concepts, Inc. (1999). *Materials Science Technology: Solids*. Pp. 4.9-4.12

www.energy-concepts-inc.com – This is a national vendor that sells the reorganized Materials Science Curriculum so that it is more “teacher friendly.” This curriculum covers many topics beyond the DOE curriculum. Energy Concepts, Inc. 404 Washington Blvd. Mundelein, IL 60060. Tel: 847-837-8191, Fax: 847-837-8171.

www.pnl.gov/education/mst.htm – This is the Web site for the Department of Energy’s Materials Science Curriculum. The site also gives a glimpse into the full document, with information and selected activities in PDF format.

Putting and Plotting

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *2-3 days*

Teacher Preparation

This case study will take two to three classroom days to complete. In this case study, student teams of three will be asked to participate in the same exact event a series of times, and plot the results. These results will then be compared to the results of a system or prototype that they create and document to insure that the ball lands on the objective spot every single time. Tolerances may be a topic of discussion that could be covered as a pre-lesson as well.

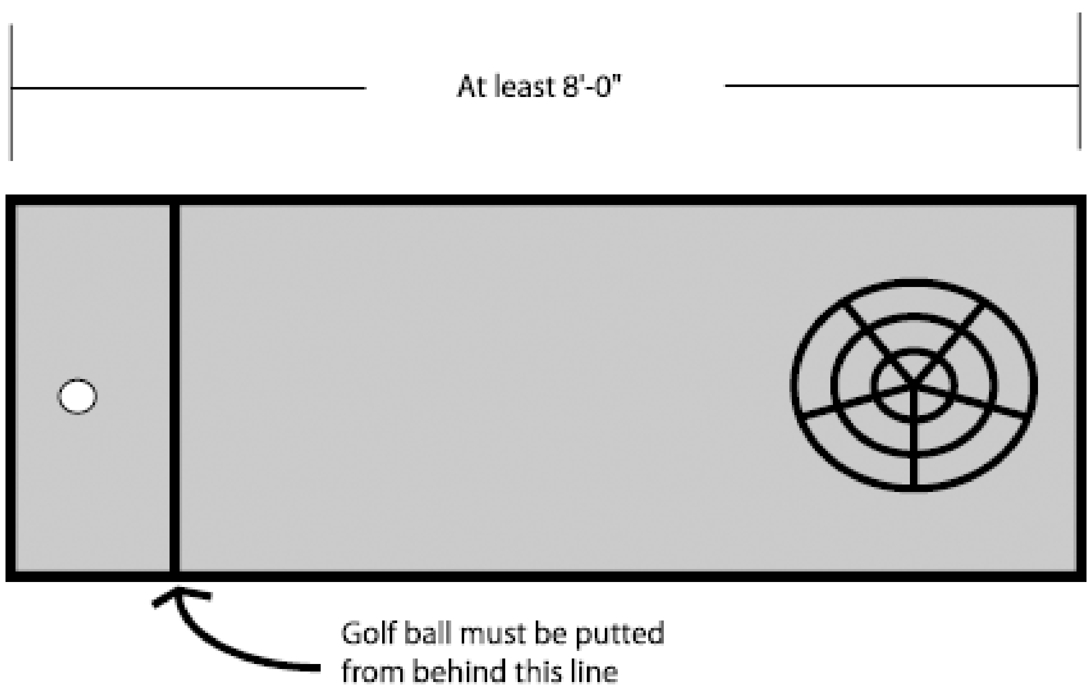
This study requires spreadsheet software, entry carpets, golf balls, putters, rulers, graph paper, and tape to locate the objective point.

Case Study

Students may or may not have been to a miniature golf course, but odds are that they have seen one or understand the concept. Problem-solving a situation can take months and years, or you may only have a few hours to get the answer. Accuracy in a solution, as well as repeatability, are both key factors.

Part A
Student teams of three will be asked to putt three golf balls on an entry carpet and hit a specific spot at the end of the carpet. Results for each putt will be plotted on a graph and compared to each member of the team. The results should be measured and plotted on a spreadsheet, with a degree of accuracy to the objective point of .125 inches.

Part B
Student teams will design a system to accurately guide the golf ball to the objective point when it is putted. The results should be measured and plotted on a spreadsheet with a degree of accuracy to the objective point of .125 inches. These results should then be compared to the results of Part A. The solution generated in Part B should be documented according to the process listed at the beginning of this unit.



Assessment

Putting and Plotting Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Plotting Data PART A	All three members' data is accurately collected and plotted.	All three members' data is collected and plotted. There are minimal discrepancies in the data.	Two members' data is accurately plotted. One member's data has discrepancies.	One member's data is accurately plotted. There are discrepancies in two members' data.	
Implemented System	The system as designed is well thought out through brainstorming processes, and implemented.	The system design is well thought out through brainstorming processes but has some trouble being implemented.	The system design is well thought out but doesn't use the brainstorming process, and is implemented.	The system doesn't use the brainstorming process and has trouble being implemented.	
Plotting Data PART B	All three members' data is accurately collected and plotted.	All three members' data is collected and plotted. There are minimal discrepancies in the data.	Two members' data is accurately plotted. One member's data has discrepancies.	One member's data is accurately plotted. There are discrepancies in two members' data.	
Comparison of all Data	All three members' data is accurately collected, plotted, and comparisons are made and explained.	All three members' data is collected and plotted. There are minimal discrepancies in the data. Comparisons are made and explained.	All three members' data is collected and plotted. There are minimal discrepancies in the data. Comparisons are made but not explained.	All three members' data is collected and plotted. There are minimal discrepancies in the data. Comparisons are not made and not explained.	

Resource

www.glpbooks.com – Great Lakes Press Web site.

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Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *1-2 days*

Teacher Preparation

This case study will take one to two classroom days to complete. Make sure that you are familiar with the calculations in the case study so that you can provide feedback to students while they are working. Most students will overlook the fact that the heat supplied in the room initially is from the people in the room and is calculated in the number of BTUs that they give off. In the final equation, students are trying to solve for delta T. They should incorporate the total number of BTUs generated by the people into the answer for the final calculation—it is the number of BTU's that must be lost before the heat has to be turned on.

The number is very close to the inside temperature. A discussion with the class should cover insulation factors, cost analysis, start-up costs of building a structure with cheaper materials initially, and long-term costs associated with heating and cooling. If you are in a warmer climate, the calculation is the same, but you will have to edit the information to reflect the need to cool the environment rather than heat it.

NOTE: This is mandatory information for you and your students to learn before the Emergency/Homeless Shelter case study is done in Unit 5.

Case Study

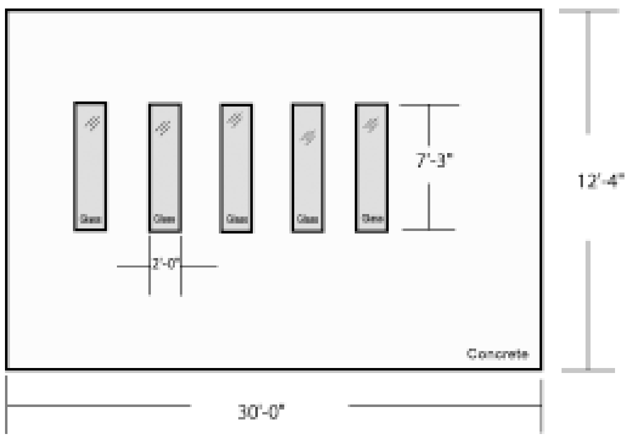
The history of school buildings has seen many different techniques and materials used to build these structures. In the early twentieth century, many of the school buildings were built out of concrete and glass as the main components. Currently these older buildings are still providing shelter and protection from the elements. The question remains—are they cost-effective in the long run, or are we throwing money out the window? In many states across the nation, students always complain in October or November that the rooms in their schools are too cold. You have been charged with calculating when the heat supplied by the number of students in the room (30) will no longer keep the temperature at 68 degrees Fahrenheit. The answer will determine at what outside temperature the janitor will have to turn on the heat.

Part A

- 1 BTU or British thermal unit is an English standard unit of energy. One BTU is the amount of thermal energy necessary to raise the temperature of one pound of pure liquid water by one degree Fahrenheit at the temperature at which water has its greatest density (39 degrees Fahrenheit). This is equivalent to approximately 1055 joule (or 1055 watt-seconds).
- 1 WATT is equal to 3.413 BTU/Hour.
- 1 person is equal to 108 watts.
- 1 average person gives off heat equal to 368.604 BTU/Hour.
- R-Value is the resistance level of the material. This number can be associated with building materials lists or can be derived from an experiment that can be done to determine the R-value of a material.
- U-Factor is the combined thermal conductivity (1/R).
- Delta T is the change in temperature. For example, if outside it is -20 degrees Fahrenheit and inside it is 70 degrees Fahrenheit, the delta T is 90 degrees Fahrenheit.

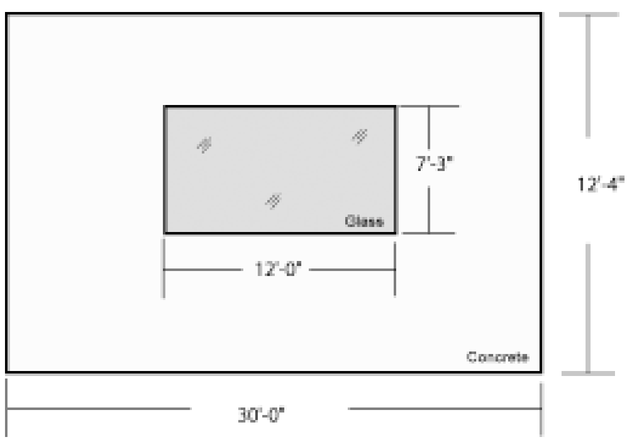
Part B

Calculate the area of the materials being used. The answers should be in feet and converted to decimals. The R-Value for the glass is .89 and the concrete is 1.11. The ceiling's R-Value is .08 per inch thickness.



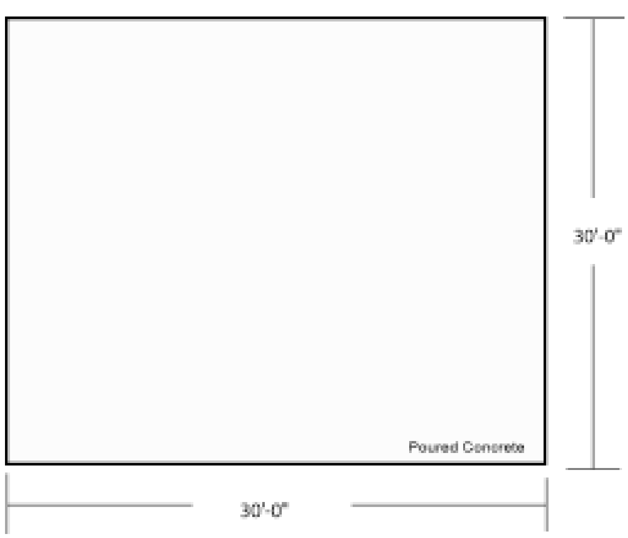
West wall total =_______(A_W)
West wall glass =_______
West wall concrete =_______

R-Value of glass = .89
R-Value of concrete = 1.11



North wall total =_______(A_n)
North wall glass =_______
North wall concrete =_______

R-Value of glass = .89
R-Value of concrete = 1.11



Ceiling total =_______(A_c)

R-Value per inch of concrete =.08

Total R-Value for 5" thick poured concrete ceiling =_________

Part C

Calculate the R-Value for wall sections. Note that these are proportional calculations. If there were multiple layers, the layers would be added up and totaled. If there were layers and proportions in the wall section, both calculations would have to be completed.

West Wall (area of glass)(R-value of glass)+(area of concrete)(R-value of concrete)=R_w
North Wall (area of glass)(R-value of glass)+(area of concrete)(R-value of concrete)=R_n
Ceiling (area of concrete)(5 inches thick)(R-value per inch)=R_c

Calculate overall R-Value

R_w=________
R_n =________
R_c=________

$$\frac{R_w+R_n+R_c}{A_w+A_n+A_c} = \text{Rvalue overall} = \underline{\quad ? \quad}$$

Plug your answers into this equation to get the overall R-Value.

Calculate U Factor

$$\text{U Factor} = \frac{1}{\text{R-Value overall}} = \underline{\quad ? \quad}$$

Plug the answer from the last calculation into the denominator.

Calculate Heat loss

(Area)(U Factor)(Delta T)=Heat loss in BTU's/Hour

Plug in the variables you know and solve for those that aren't known.

Question:

What is the outside temperature when the students' own body heat will not keep the room at 68 degrees Fahrenheit? Why?

Assessment

Areas are answered correctly in PART A	10 points
Calculations are complete and correct in PART C	30 points
The final question is answered and elaborated	20 points
Total Points:	60 points

Resources

Mull, Thomas E. (1997). *HVAC Principles and Applications Manual*. The McGraw-Hill Companies, Publisher. ISBN: 007044451X.

This is an on-the-job handbook for beginning or experienced engineers, providing information on design, applications, and code compliance without delving into theory and complex mathematics. It includes such topics as basic scientific principles, climatic conditions, infiltration and ventilation, external heat gains and cooling loads, acoustics and vibrations, human comfort, fans and central air systems, an introduction to electrical systems, and controls for air distribution systems. The Appendices contain tables of technical matter such as the thermal properties of building materials and the average winter temperature for major U.S. cities.

Ping Pong Launch

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *2-3 weeks*

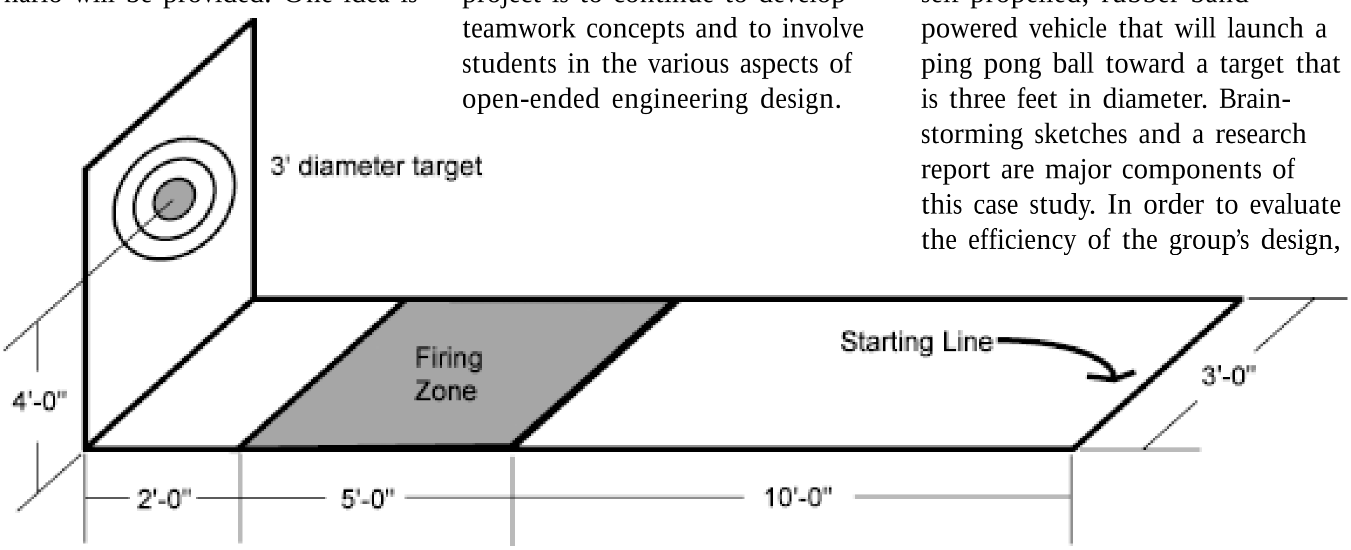
Teacher Preparation

This case study will take ten to fifteen classroom days to complete. Teachers should prepare for this case study by gathering materials that could be used to build the prototype. Often students assume that all materials for a given scenario will be provided. One idea is to keep things in bins that have been recycled from many different case studies. Students are welcome to use anything that is there, provided they return it.

Case Study

The primary purpose of this project is to continue to develop teamwork concepts and to involve students in the various aspects of open-ended engineering design. Performance, economics, reliability, aesthetics, and manufacturing processes will be factors leading to your final design from the various alternatives.

The three-member team will design, document, and construct a self-propelled, rubber-band-powered vehicle that will launch a ping pong ball toward a target that is three feet in diameter. Brainstorming sketches and a research report are major components of this case study. In order to evaluate the efficiency of the group's design,



each team will compete on the course shown on the previous page.

Given:
The testing floor:

- Will be located in the gym or the hallway.
- Will have a lane that is 3 feet wide by 17 feet long (marked by tape).
- Will have a target that is 3 feet in diameter (see sketch).
- Rubber bands, size #64 or smaller, may be used.
- Ping-Pong balls (True-Play Star brand) will be used.

A parts list is required of each design team, to be submitted with the design proposal/research report.

A sample of what the parts list might look like:

Part #	Part Name	Dwg. #	Qty/Unit	Material	Size	Make or Buy	Cost
1050	Motor Shaft	1000	1	Mach. Screw	8-32 x 1.0"	Buy	$0.12
2200	Coupler	1003	1	Plastic	1/16 ID Nylon Tube	Make	1.42
3250	Propeller	1005	1	Aluminum	12 ga x 2	Make	0.18
3251	Prop hub	1000	1	Aluminum	14"dia	Buy	0.18
3252	Hull	1000	1	Styrofoam	9x4x3	Buy	0.24
3253	DC Motor	1000	1	"See Drawing 1000"		Buy	4.99
3254	Solar Cell	1009	1	"See Drawing 1009"		Buy	5.99

Design Restrictions

1. The device must leave the starting line under its own power. The devices may employ manual brakes (i.e., human fingers on the wheels or power source) to position them on the track. The operator may then merely "let the device go" without pushing.

2. Once the vehicle is started, no external communication, interaction, or influence of any kind is allowed (i.e., the system must be completely autonomous).

3. The device must fit into an 18 x 18 x 18-in. box.

4. Travel and launch capabilities must be accomplished through the use of rubber bands only. The Ping-Pong ball must be launched within two (2) minutes.

5. Any number and combination of rubber bands (not to exceed #64 in size) may be used.

6. No part of the launcher may be left behind at the start line.

7. The device must launch the Ping-Pong ball while in motion.

8. Only one shot per pass will be allowed. The pass is considered complete once the ball has been launched.

9. True-Play Star brand Ping-Pong balls will be the official balls.

Scoring
The objective is to fire the Ping-Pong ball within the designated launch area and hit the target. Scoring is based on how close to the bull's-eye the ball hits. Ten (10) points will be awarded for each bull's-eye. Five (5) points will be awarded for hitting the second ring, and two (2) points will be awarded for hitting the outer ring. Five (5) points will also be awarded for traveling (in bounds) the length of the 10-ft. approach lane, and five (5) additional points will be awarded for simply launching from within the firing zone. In the event of a tie, the highest average score for the three shots will be the winner. In the event of an average score tie, the fastest average time from start to final stop will be the winner.

Assessment

Objective	Run #1	Run #2	Run #3
1. Traveling the length of the10-ft. “approach lane” (5 pts.)			
2. Launching within the “firing zone” (5 pts.)			
3. Stopping within the “stopping zone” (5 pts.)			
4. Bull’s-eye (10 pts.)			
5. Second Ring (5 pts.)			
6. Outer Ring (2 pts.)			
* Time of run (2 min. limit)			
TOTALS			

AVERAGE SCORE (used as a tie breaker) ______

AVERAGE TIME (perfect score tie breaker) ______

Ping Pong Launch Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Design Proposal/ Research Report	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demonstrating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	
Brainstorming and Sketching	Sketches are complete, with detail and relevant materials and labels.	The sketches are complete, using relevant materials and labels.	The sketches are complete, using relevant materials.	The sketches are incomplete, but use relevant materials.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disordered, or is confusing.	
Parts List	The parts list is complete, with detail and relevant materials and labels.	The parts list is complete, using relevant materials and labels.	The parts list is missing information or dimensions.	The parts list is incomplete, but an attempt was made.	
Objective Scoring—enter the appropriate score from the chart at the top of the page.	→	→	→	→	

Resources

www.tcnj.edu/~asper/

This case study has been adapted from "Fundamentals of Engineering Design," a course taught by Norman L. Asper, Ph.D. Professor in the Department of Engineering at the College of New Jersey, P. O. Box 7718, Ewing, NJ, 08628.

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Scrambler Vehicle

Content: *Nature and development of technology, Technological progress, Rate of technological development*

Time: *2-4 weeks*

Teacher Preparation

This case study will take ten to twenty classroom days to complete. Materials vary for the construction of this prototype and can be from the simplest type to the complex composites that are used in the picture on the next page. Stopwatches, a gym for testing, and the end barrier are the physical things you will need to conduct the testing. Familiarize yourself with the scoring sheet that follows, as it is rather complicated in nature.

Case Study

The contestants will design and build a purely mechanical device that will transport a large, Grade A, uncooked chicken egg a distance of 8 to 12 meters along a straight track as fast as possible and stop as close to the center point of a terminal barrier as possible without leaving a 2-meter wide lane. The intent is to complete the run at the center of the straight lane. The distance to be traveled will be announced at the beginning of the event, after the devices have been impounded. The device must be a single unit. The only source of energy allowed for moving and stopping the device must come from the falling of a mass not to exceed 2.00 kg. Scrambler systems will be impounded prior to the event. Safety goggles should be worn by the students during vehicle preparation and testing when warranted.

Construction

a. The entire device, in ready-to-launch configuration, must fit inside a 1 m cube. The entire device must start behind the start line. The pointed tip of the egg must start directly even with the start line.

b. The falling mass must not exceed 2.00 kg. Any part of the device (such as swing arm and any of its attachments) that has gravitational potential energy at the start of the run that decreases as the device moves down the course, is to be considered part of the falling mass. The event supervisor will measure the mass. The mass must be able to be removed quickly and easily for measuring. It is suggested that the device be impounded with the falling mass already detached.

c. An uncooked chicken egg (which will be provided at the site – 1 per team) should be mounted on the front of the device so that the pointed end of the egg extends at least 2 cm in front of the most forward part of the transport. Initially, the egg must be 5-15 cm above the floor. It must be mounted so that the egg will make first contact with the barrier in case of collision. Tape will be provided to secure the egg to the device if needed, but no tape may be placed on the front 2 cm of the egg. If any part of the device collides with the barrier, there will be a penalty.

d. The device must have a flat, rigid, unmodified backstop behind the egg made of at least a 5 cm x 5 cm piece of 3/4-inch thick plywood or similar hard board, and the egg mount must not be padded. The rounded end of the egg must rest against the rigid backstop. No harness devices may be used to cradle the egg. Once the falling mass has been set in motion, the vehicle may not be touched until it comes to a complete stop.

e. Any accessory equipment for the device (such as springs, rubber bands, etc.) must initially be in a completely relaxed state.

f. No chemical substances may be applied to the wheel surfaces.

g. All sighting or aligning devices must be permanently attached in a fixed position to the

Scrambler. If a target is needed, it must be impounded with the device. The target cannot stay in the track but must be removed before the device starts its run.

Testing

a. The competition will be on a relatively smooth and level 2-meter-wide straight lane.

b. The Scrambler must finish as close as possible to the center of the terminal barrier without leaving the 2-meter lane. The terminal barrier (for timing purposes) will be located 8-12 meters from the starting line. (This can be placed at the following intervals with varying difficulty to which students can adjust the machine: whole meter, half-meter, and tenth of a meter.) The entire device must be behind the starting line and within the 2-meter width of the track when the mass is released. The pointed tip of the egg can be placed anywhere along the starting line, even with it, and timing will begin when the falling mass is released. Timing will end when the device comes to a complete stop.

c. Students may not touch or guide the egg transport in any way once the falling mass has been released.

d. Stopping mechanisms must work automatically. The device may not be tethered or remotely controlled in any way to guide it or to make it stop. No electrical or electronic brakes may be used. Students will not be allowed to back the car up on or near the track in order to set the braking mechanism.

An instructor poses with the composite scrambler prototype vehicle. Its structure is 100% carbon fiber and Kevlar with a honeycomb core.

e. The contestants may hold and release the device, or they may hold and release the falling mass in order to start its motion. However, they CANNOT hold both the device and the mass. The device cannot be pushed or pulled by hand. All of its propulsion must come from the falling mass. The uppermost part of the falling mass may not be higher than 1 meter from the floor.

Assessment

a. Performance value = 3x (running time in seconds) + (stopping distance in cm) + prediction score. Low score wins. The stopping distance will be measured in a direct line from the point where the terminal barrier meets the center of the lane to the pointed tip of the egg.

b. Run Penalties: If the egg breaks or is cracked enough to leave a wet spot on a paper towel or if any part of the device other than the egg makes contact with the barrier or if any part of the device runs outside the lane (even for only part of the run), that run will be given a run penalty.

c. Construction Penalties: If the device violates any of the construction requirements (e.g. falling mass > 2 kg, egg mount too high, device too large, etc.), the device will be given construction penalties equal to the number of violations.

d. Teams will normally be allowed two official runs, and the higher-ranking run of the two will be accepted. A team will NOT be allowed a second run if the egg is broken (as defined above) on the first run. If the egg is broken on the second run, the higher ranking run will be accepted. Scramblers with no construction penalties that have a run with no run penalties will be ranked first, with the lowest performance value taking first place. Scramblers with no construction penalties but with run penalties will be ranked next. Scramblers with construction penalties are ranked next and so on. No team that receives any type of penalty on its chosen run can rank ahead of one that did not.

e. Teams will be given a total of ten minutes to prepare and run their devices. If the apparatus cannot start at least one run within this time, the team will be given one (1) participation point. If the device has started a run (1st or 2nd) before the ten-minute time period expires, it will be permitted to complete that run. Between runs, cars may be adjusted, but not altered by adding or subtracting weight. This will count as part of the ten minutes. The time for judges to measure the stopping distance will not be included in the five minutes.

SCORING SHEET

SPECIFICATIONS (10 points each):

_____ Ready-to-launch device within 1-meter cube?
_____ Single unit and transports mass.
_____ Falling mass and attachments $\leq$ 2 kg?
_____ Entire device behind line?
_____ Front 2 cm of egg exposed?
_____ Egg 5-15 cm above floor and on line?
_____ Egg touches backstop and is unpadded?
_____ Egg is rigged for first contact?
_____ Pointed end of egg even w/ start line.
_____ No chemicals applied to wheels.
_____ Mount is legal size and height.
_____ No other energy source propels car?
_____ Device has legal stopping system? (No tether, remote control, or electronic brake.)
_____ Falling mass height $\leq$ .75 m?
_____ POINT TOTAL

DOES DEVICE MEET SPECS?
_____ YES ____ NO

If no, the number of Construction Penalties = _________

RUN #1: Performance Value = 3 X (___________sec.) + (__________cm.) = _____________
Running Time Stop Distance Final Score

RUN PENALTIES:
Egg broken? ____ Vehicle touched barrier? _____ Lane violation? _____

Did the vehicle travel at least one meter? ______ If NO, rank the vehicle behind all others if this run is used.

RUN #2: Performance Value = 3 X (___________sec.) + (__________cm.) = _____________
Running Time Stop Distance Final Score

RUN PENALTIES: Egg broken? ____ Vehicle touched barrier? _____ Lane violation? _____

Did the vehicle travel at least one meter? ______ If NO, rank the vehicle behind all others if this run is used.

NOTES FOR SCORING:

1. CIRCLE the BEST SCORE (probably the one with the fewest “run” penalties, then the lowest score).
2. REMEMBER that ALL VEHICLES ARE GROUPED (for scoring purposes) by the EXACT NUMBER of CONSTRUCTION PENALTIES.

Placing cars is done according to the following:

1. First, according to how many construction penalties (CP), which means that any car with NO CP is placed ahead of all other cars, and so forth.

2. Within any group according to the number of CP, the cars are then placed in order of the number of run penalties (RP) they have. Again, this means that a car with zero RP is first within a group that was first established by the CP.

Total score possible is 180 points plus the average score of runs one and two. The first section will always be given; however, the second section will vary based on the vehicles constructed from year to year. You may add point values to required brainstorming sketches and drawings as well as any other sections that may not be mentioned here.

Resources

www.soinc.org/ – This case study was adapted from the rules of the national Science Olympiad competition.

Academic Connections – Unit 4

Mathematics

- Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more complicated cases.
- Judge the reasonableness of numerical computations and their results.
- Approximate and interpret rates of change from graphical and numerical data.
- Explore relationships (including congruence and similarity) among classes of two- and three-dimensional geometric objects, make and test conjectures about them, and solve problems involving them.
- Apply informal concepts of successive approximation, upper and lower bounds, and limit in measurement situations.
- Use unit analysis to check measurement computations.
- Solve problems that arise in mathematics and in other contexts.
- Apply and adapt a variety of appropriate strategies to solve problems.
- Recognize and apply mathematics in contexts outside of mathematics.
- Use representations to model and interpret physical, social, and mathematical phenomena.

Science

- Use technology and mathematics to improve investigations and communications.
- Recognize and analyze alternative explanations and models.
- Evidence and reasoning in inquiry.
- Ratios and proportionality.
- Describing change.
- Averages and comparisons.
- Correlation.
- Statistical reasoning.
- Identify a problem or design an opportunity.
- Propose designs and choose between alternative solutions.
- Implement a proposed solution.
- Evaluate the solution and its consequences.
- Communicate the problem, process, and solution.
- Understandings about science and technology. Science and technology in local, national, and global challenges.
- Science as a human endeavor.
- Influences of social change.

English

- *Lab reports*
  Students will link their English writing skills with this course through lab reports. The students should use complete sentences to describe their thoughts and activities.
- *Documentation*
  Technical data and information is recorded as part of the activities.
- *Essays*
  These should be used as a tool to summarize and synthesize research. These may be given as individual assignments or could be included as part of a larger assignment. Teachers should develop grading criteria and inform the students before the essay is started.

Chapter 2, Unit 5

Design

Standards for Technological Literacy **Standards Addressed in Unit 5**

Unit 5 addresses the following *STL* standards:

- **Standard 8** Students will develop an understanding of the attributes of design.
- **Standard 9** Students will develop an understanding of engineering design.
- **Standard 10** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
- **Standard 11** Students will develop the abilities to apply the design process.
- **Standard 16** Students will develop an understanding of and be able to select and use energy and power technologies.

Big Idea

Design

Student Assessment Criteria – Design

Achievement Level / Sub-concept	Above Target 3	At Target 2	Below Target 1
Systems	**Creatively and with depth, appraises** the future, **thinks globally** and beyond, and takes into account the individual and collective needs and desires of the global community.	**Appraises** the future, **thinks broadly**, and takes into account the individual and collective needs and desires of the global community.	**Appraises** the future with some **difficulty**, **thinks narrowly** about possibilities, and **has difficulty** taking into account the individual and collective needs and desires of people.
Processes	Generates a **wide range of creative ideas**, using a **variety of techniques,** and takes **all** possibilities into consideration.	Generates **creative ideas**, using **several techniques,** and takes **all** possibilities into consideration.	Generates **ideas**, using **few techniques,** and usually takes the first of a **few** possibilities into consideration.
Resources	**Creatively** sketches, draws, and describes ideas; develops computer, mathematical, and physical models; prototypes and tests promising design possibilities; **accurately** generates, analyzes, and draws conclusions from data.	Sketches, draws, and describes ideas; develops computer, mathematical, and physical models; prototypes and tests promising design possibilities; generates, analyzes, and draws conclusions from data.	Sketches, draws, and describes ideas with **minimal effectiveness**; has **difficulty** developing computer and mathematical models, but has some **success** with physical models; prototypes and tests promising design possibilities but has **difficulty** generating, analyzing, and drawing conclusions from data.
Impacts	**Creatively and convincingly** presents and demonstrates design ideas using **a variety** of presentation media and techniques, including test data, models, and prototypes.	Presents and demonstrates design ideas, using **a variety** of presentation media and techniques, including test data, models, and prototypes.	Presents and demonstrates design ideas with **minimal effectiveness**, using **several** techniques, including test data, models, and prototypes.

Student Learning Experiences

Chair Design
Solar Car
Fling It!
Project "Recycle"
Emergency/Homeless Shelter
The Walker

As a set of learning experiences, the following *STL* content standards and corresponding benchmarks are addressed: Standard 8, Benchmarks H, I, J, and K; Standard 9, Benchmarks I, J, K, and L; Standard 10, Benchmarks I, J, K, and L; Standard 11, Benchmarks M, N, O, P, Q, and R; Standard 16, Benchmarks J, K, L, M, and N; and Standard 20, Benchmarks J, K, L, M, and N. However, if you choose to use only a specific activity, please refer to Appendix B to determine exactly which standards and benchmarks are being addressed by that learning experience. See **Appendix B** for a complete listing of the *STL* content standards.

Acceptable Evidence of Student Understanding

1. Document evidence of daily progress with the use of a lab report or journal.
2. Design and build an ergonomically correct chair according to criteria.
3. Define the term anthropometric.
4. Correctly use trigonometry to calculate true material lengths, given angle and dimensional constraints.
5. Develop scale models for use in presentation and creation.
6. Define the term ergonomics.
7. Correctly use Gantt charts to plan design solutions.
8. Research and correctly use photovoltaics as a power source.
9. Define the term aerodynamics.
10. Correctly use Computer Aided Design (CAD) software or hand drawings to plan a prototype.
11. Correctly use calculations to determine theoretical velocity and theoretical range.
12. Document the group process in designing a prototype.
13. Participate in group decision making.
14. Problem-solve in a group to complete a group task.
15. Define the abbreviation RFP.
16. Correctly use thermodynamic calculations to determine heat loss.
17. Correctly calculate air infiltration needs for humans.
18. Define the term 50 percentile.
19. Design a low-cost structure made out of 90% cardboard that will allow people to survive outside during very cold weather.

Special note: Please keep in mind that criteria must be developed to measure the evidence that students provide in demonstrating their levels of understanding—what are we looking for and how will we know it when we see it? For example, if students are asked to build a model, how will we know if it's a good one?

When considering achievement levels and helping students to understand how they might improve, it will be necessary to know what we mean by terms such as effectively, efficiently, adequately, creatively, thoughtfully, mostly, clearly, minimally, marginally, correctly, safely, systematically, randomly, logically, thoroughly, introspectively, insightfully, and meaningfully. (See **Appendix D, Acceptable Evidence Glossary**, for definitions.)

Overview

Design is a process used by engineers to generate products, processes, and systems based on the recognition of a need. The following are significant factors in the design process that students should use in all case studies.

Functionality – The product or solution must fulfill its intended purpose. Imagine a table used by students for studying. If a person were to stand on the table, would it support the weight? Was this table intended to support a person's weight? It is to be noted that the table's original design was to support something other than a person's weight. The team that developed the table had not intended it for the excessive weight, and the table is being used in a way for which it is not intended.

Quality – The product or solution must be designed to meet certain minimum standards. The soles of shoes will be an example for quality. Students were asked how long they think their shoes will last. Most said that they use them for no more than two years. So then why, if most of our day is spent walking or running on harder surfaces, such as concrete, are our shoes bottomed with a softer surface like rubber? The answer is comfort.

When a worker recently complained to his employer of being tired all the time and of chronic back pain, he was sent to the doctor for evaluation. The doctor found the problem to be his shoes. Improper support for his feet led to the back pain and fatigue. Quality has a relationship to the conditions of the item's intended use. This spin-off of functionality is important because quality is defined according to the proper or improper use of the item. Are casual shoes intended to be used to play basketball, and if so, would there be quality issues when they are used in the incorrect environment? Quality has to be evaluated within the context of use, and can only be properly evaluated when the context is correct for the item's intended use.

Safety – The product must be designed to comply with codes and regulations to provide safe use and operation by the user. Americans are becoming more safety conscious than ever, in everything from our cars to our homes. Air bags have become the norm in passenger vehicles since 1997; however, some have posed deadly problems. The force with which they are activated in an accident has injured many people, some of them fatally. These early air bags, intended to save lives, sometimes deployed not as the result of an accident. Sometimes incorrect installation of a child car seat (facing the windshield) injured and killed small children from the inflating force of the air bag. How are drivers going to navigate their vehicles when an air bag is unnecessarily deployed, blocking their vision? The first generation air bags have been redesigned many times. For example, a switch exists to turn off the passenger seat air bag for several different reasons, ranging from a person who is tall to one who is very short. A driver now has the option to disable the air bag.

Ergonomics – The product must be designed so that the user can operate it with ease and maximum efficiency. Ergonomics is also called human factors engineering. Designing chairs for genuine long-term or short-term comfort is a part of ergonomics. One famous fast food chain restaurant designs the chairs so that customers are comfortable only for the time it takes to eat the kind of food served. The customer will then leave, so employees can clean the table and chair for the next person.

Imagine this scenario: You and your wife are going to be traveling with your three children and want to buy a new conversion van. At 6'3" tall, you are larger than the average person. Your wife is 4'11". You test drive the van, but she doesn't want to. The van is purchased, and the trip begins. You begin the drive, until fatigue sets in, and then turn the wheel over to your wife and get some sleep. When you awake from your nap, you notice that you aren't near the planned city; your wife was driving at only 45 MPH on the expressway. When asked why she was going so slowly, she replied, "It was as fast as I could go, my feet could not press any farther down on the pedals."

The manufacturer had never considered that an adult only 4'11" in height would drive a full-sized conversion van. Manufacturers have begun to consider more in-depth ergonomic factors in their designs and their marketing plans toward smaller people.

Appearance – The appeal of a product is based on the selection of materials, processes, finish, color, or shape. If you, as a potential consumer, don't like what a finished product looks like, you are less likely to purchase it. For example, a "new" baseball hat is one that is colorful and clean, with no rips or tears. However, in some stores "new" baseball hats have torn, pre-formed, and dirty bills. Some people have different definitions of what is new and what is stylish. Companies invest millions of dollars in major marketing campaigns to get consumers to buy into their ideas. Ultimately though, it is up to the consumer to make the decision to purchase the product.

Environmental Considerations – The product must be designed so that it does not adversely affect the environment. Many people immediately think of oil dripping from their cars and smog over a city. While both of these adverse conditions are included in this category, there are also many others. Wind tunnels serve as an example. Planning commissions and city engineering departments continue to construct large buildings amongst large buildings and neglect to do any kind of wind analysis on the new structures or their surrounding environment. As a result, a five-mile-an-hour breeze could be increased by the configuration and heights of the buildings into a fifteen-mile-an-hour or more wind.

Economics – The product must be produced at the least cost without sacrificing safety. Engineers are poised to keep costs down to increase company profit. Often they take cuts in production, shortcuts that lead to unsafe products. More often than not we, the public, are not concerned, nor do we know about these actions taken by companies until something drastic happens. Usually it takes a death or a disaster to focus our attention.

For example, consider the Sam Poong department store in Japan that collapsed, killing 1,500 people. Store management left the building early in the morning after cracks appeared in the walls and ceiling, but they did not tell employees or customers of the danger. Shopping throughout the building went on as usual. Then the fifth floor collapsed onto the fourth, setting off a chain reaction all the way to the ground level. The building collapsed because of poor building codes and their enforcement, paired with the fact that the firm doing the concrete work added entirely too much water to the concrete mix to lessen the costs, creating a very weak concrete structure.

Teacher Preparation

The suggested learning activities in this unit are teamwork-oriented. Teachers should inform students about strategies and tools to effectively work in teams. Conflict resolution may be another topic that can be covered in detail before starting any case study or activity.

Unit 5 Content Outline

- I. Design
  - A. Generate products, processes, and systems based on the recognition of a need
    - 1. Functionality
      - a. Product or solution has to fulfill its intended purpose
        - 1.) Screwdrivers aren't designed to be used as hammers
        - 2.) Tables aren't designed for people to stand on
    - 2. Quality
      - a. Product or solution must be designed to meet certain minimum standards
      - b. In relationship to the conditions of the item's intended use
        - 1.) Quality is defined according to the proper or improper use of the item
        - 2.) Quality has to be evaluated in the context
          - a.) Wearing dress shoes to play basketball
          - b.) Wearing tennis shoes for everyday use
    - 3. Safety
      - a. Comply with codes and regulations
      - b. Provide safe use and operation by the user
        - 1.) Air bags
          - a.) Early design intended to save lives
          - b.) Force of impact injured and sometimes killed users
        - 2.) Child car seats
          - a.) Often installed incorrectly by user
          - b.) Design sometimes failed, injuring child
    - 4. Ergonomics (human factors engineering)
      - a. Percentiles
        - 1.) 50 percentile = average of all people in a culture
        - 2.) 90 percentile would be toward largest of people
        - 3.) 10 percentile would be toward smallest of people
      - b. Culture dictates physical characteristics
        - 1.) European
        - 2.) Chinese
        - 3.) African tribal
      - c. User can operate with ease and maximum efficiency
        - 1.) Chair design
          - a.) For long-term use
            - (1.) Recliners in home
            - (2.) Desk chairs at work
          - b.) For short-term use
            - (1.) Fast food restaurants
            - (2.) Classrooms
        - 2.) Brake and gas pedals in vehicles
          - a.) American females need pedals closer in most vehicles
            - (1.) Move seat up, then too close to air bag
    - 5. Appearance/Aesthetics
      - a. The appeal of a product is based on:
        - 1.) Materials
        - 2.) Processes
        - 3.) Finish
        - 4.) Color
        - 5.) Shape
      - b. If consumers don't like what they see, they are less likely to buy it
        - 1.) First Toyota cars
        - 2.) Pre-worn clothing (i.e. ripped hats, jeans with holes in them, etc.)
    - 6. Environmental considerations
      - a. Product must be designed so that it does not adversely affect the environment
        - 1.) Wind tunnels
        - 2.) Decrease of vegetation in an area, decreasing oxygen generation and consumption of CO_2
    - 7. Economics
      - a. Produced at least cost without sacrificing safety
        - 1.) Costs down
        - 2.) Profits up
      - b. Sometimes cuts are made to keep profits up
        - 1.) Cuts sometimes lead to unsafe products
          - a.) Cuts in production
          - b.) Cuts in materials
          - c.) Cuts in safety systems
        - 2.) Public is not concerned until something drastic happens
      - c. (e.g.) Sam Poong department store in Japan
        - 1.) Collapsed, killing 1,500 people
        - 2.) Management left after cracks appeared in walls
          - a.) Didn't tell employees, customers
        - 3.) People still shopping, employees still working
        - 4.) Building collapsed because of poor building codes
          - a.) Too much water in the concrete mix to lessen the costs
          - b.) Created a very weak concrete structure
    - 6. Analyze designs in nature
      - a. Electricity in nature (eels and catfish)
      - b. Cold light (fireflies)
      - c. Jet propulsion (squids)
      - d. Flight (insects, birds)
      - e. Mechanisms (human joints)
      - f. Structures (spider webs, beaver dams)
      - g. Special senses (bats sonar, migration timing)

Suggested Learning Activities

Chair Design

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *2-3 weeks*

Teacher Preparation

This case study will take ten to fifteen classroom days to complete. Students need space to accommodate production of full-scale models. A drafting room with a sink is an appropriate space for this learning experience, where desks can be kept clean for drafting, and work tables are available for cutting and laminating large sheets of cardboard. Paper cutters can be used, but the majority of cutting work is done by hand with box cutters, metal straight edges, and large cutting boards.

The instructor should disseminate information regarding structural elements and forces: columns; beams; trusses; dead, live, and dynamic loads; concentrated and uniformly distributed loads; compression; tension; shear; bending; rotational forces; and corrugated cardboard as a building material. A lesson on isometric drawing (circles/arcs and angles) is given by the instructor to the entire class (three thumbnail sketches and one isometric sketch on isometric graph paper from each student is given to product engineer). Trigonometry and dimensions instruction: The teacher will review anthropometric data with the class and demonstrate how to calculate true material lengths, given angle and dimensional constraints. All dimensions are put on the isometric sketch. The sketch will need to be copied for other team members to use. Model-making techniques demo lesson: safety and the proper use of cutting knives, and tips for cutting, scoring, laminating, and temporary taping of cardboard while preserving the classroom desks and worktables. (All members of the team will work on the final, full-scale chair model.)

Case Study

The challenge for this case study is to design and build an ergonomically correct chair based on the measurements of the students in the class. The chair must be able to support a 200-pound person, and will be made from corrugated cardboard. The criteria for the design is in the chart below.

1. The chair must have a seat and a back. Arms are optional.
2. Measurements for the chair will be based on statistical class data.
3. Required angles: Back tilt = 45-60 degrees   Seat lift under legs = 15 degrees
4. There can be no fewer than three legs if they are separate.
5. The chair must support a person who weighs 200 pounds.
6. The chair must be comfortable* to sit in.
7. The chair must be made from corrugated cardboard.
8. Glue can be used for the outer skin of the chair and to laminate sheets of cardboard only (three sheets maximum).
9. Masking tape or duct tape can be used for temporary support only. None can be part of the final solution.
10. The exterior of the chair and overall appearance should be aesthetically* pleasing.
11. A cost analysis of all the products used (even if not in the final solution) is required.
12. A research report is required. All appropriate information should be formatted and included in the report.

* These areas are subjective in nature, and a scale should be determined by the class to evaluate the features.

Students will begin this case study by completing initial project research for historical references, design ideas, ergonomic and material strength data. This Web-based search should gather any and all appropriate data, pictures, graphs, and information in order to detail the basis for this case study. Teams of three will be formed at random. Job assignments within the team are:

- Structural Engineer
  The structural engineer is responsible for:
  1. The initial design and testing of materials, joints, and connections.
  2. Computations of ultimate strength and safety margin of structure.
  3. The structural drawings (two cross sections).
  4. Structural stability of the prototype and the structural journal and analysis of the prototype.

- Ergonomics Engineer
  The ergonomics engineer is responsible for:
  1. Collection of the anthropometric data.
  2. Ensuring that all dimensions meet all parameters and constraints on all drawings.
  3. Orthographic and isometric CAD drawings. Dimensions on models (preliminary and final prototype).
  4. The ergonomic journal and analysis of the prototype.

- Product Design Engineer
  The product design engineer is responsible for:
  1. Compiling the brainstorming sketches (three from each member).
  2. Final chair design solution and fabrication.
  3. Insuring that the chair construction meets all design/comfort criteria and constraints.

Team members should collect anthropometric data or measurements from every member of their team. This data should be compiled in a chart and diagram. Statistical analysis (mean, median, mode, and range) should be defined on each chart or drawing. The data obtained in individual groups is recorded by ergonomic engineers on the class chart. Ergonomic engineers meet as a group, and statistical calculations are performed. They decide which statistical measure is best suited for each of the eight chair dimensions on the anthropometric handouts. Ergonomic charts are posted in the classroom, which describe each measurement and the decisions made.

Structural designs are created and tested by structural engineers as a group (three designs minimum). Load capacity data on single-, double-, and triple-ply cardboard will also be included in the design and testing, and all findings will be recorded in structural journals (sketches must be included). Structural work, anthropometric data analysis, and design sketches will be created during the same class periods. Study models are then created from corrugated cardboard in order to incorporate design with structure (all team members participate in model making).

Drawings of the top, front, and side views, by hand or on CAD (ergonomic engineers), as well as section drawings and/or other structural views (structural engineers) are developed. Final drawings are completed, rendered, and animated if necessary. Chairs are then tested (teams meet for discussion, evaluation, and testing). Portfolios are completed, and presentations are made.

It is recommended that classes use recycled corrugated cardboard. Check for this symbol, or call your local recycling center for more information on how to obtain recycled cardboard. There are also many retailers that sell recycled cardboard.

Assessment

Chair Design Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Preliminary Design Work	The Internet research is complete, with three references. Anthropometric data is collected and analyzed. Study models and sketches are all complete.	The Internet research is complete, with two or fewer references. Anthropometric data is collected. Study models and sketches are all complete.	The Internet research is complete, with one reference. Anthropometric data is collected. Study sketches are all complete.	The Internet research is incomplete but attempted. Anthropometric data is collected. Study sketches and models are incomplete.	
CAD Drawings	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawing includes relevant information but is missing dimensions.	The drawings are incomplete, but an attempt was made.	
Cost Analysis	The cost analysis is complete and formatted, with pricing, sources, and total costs per item used.	The cost analysis is complete, with pricing, sources and total costs per item used.	The cost analysis is complete, with pricing and total costs per item used.	The cost analysis is incomplete but has some pricing available.	
Gantt Chart	The timeline is complete, with formatting tasks, dates, and persons assigned to tasks.	The timeline is complete, with formatting, tasks, and dates.	The timeline is complete, with tasks, dates.	The timeline is incomplete, but an effort was made.	
Scale Models	The Scale models are complete, with detail and relevant materials and labels.	The Scale models are complete, using relevant materials and labels.	The Scale models are missing information or dimensions.	The Scale models are incomplete, but an attempt was made.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disordered, or is confusing.	
Design Proposal/ Research Report	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demonstrating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	

Resources

www.nysatl.nysed.gov/ – The mission of the New York State Academy for Teaching and Learning (NYSATL) is to improve the achievement of all students by enhancing teachers' abilities to provide quality instruction based on standards.

This cardboard furniture activity has been adapted from the NYSTEA World of Technology series and was originally authored by Gail Atlas, Garden City Central School District, New York. For information about how to purchase the WOT publication, please visit NYSTEA.com. Published with permission of NYSTEA.

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *3-8 weeks*

Teacher Preparation

This case study will take 15 to 40 classroom days to complete. There is a suggested syllabus in the documents from the National Junior Solar Sprint Web site listed in the resource section. It takes the teacher though all the pre-lessons that need to be taught in order to complete a solar car. It is suggested that teachers follow this format and not just assign the solar car without teaching the pre-build lessons. Students should also use proper hand tools to work on their vehicles. Teachers can prepare a simple tool box per team and check those out for the building process. When students begin the build phase it is suggested that they create all the components for the vehicle and not use preformed building components (i.e., Logos, K'Nex). Using these types of parts severely inhibits the design and creative process. Students are encouraged to investigate prefabricated gearboxes for their designs. The teacher will also have to develop the timing and scoring evaluation in order to rank teams in the order they place. It is highly recommended that the teacher use the National Junior Solar Sprint format, as the information is well organized in a user-friendly format. Information may have to be reformatted to reflect the proper reading level, as the NJSS information is written in a format geared toward middle school.

Case Study

Solar power comes from the energy of our Sun, a yellow dwarf star located 93 million miles from the Earth. It is a middle-aged, mid-size star compared with the billions of other stars in the universe.

The interior of the Sun is a region very high in temperature and filled with dense gases. The Sun's core is estimated to be approximately 27 million degrees Fahrenheit. Heat and light from the Sun are produced through a process called nuclear fusion.

As early as 1877, basic solar power was used for heat in buildings, using the Sun's rays to heat iron plates, which warmed the air. Solar

APS is evaluating the performance of the latest in Dish Stirling Solar power systems at its STAR Center in Tempe. This new technology, capable of producing 25 kw of electricity, uses mirrors to focus sunlight onto a thermal receiver. The heat is used to run a Stirling heat engine, which drives an electric generator. It is one of four Dish Stirling power systems currently operating in the country. This highly efficient solar energy production system also can use alternative fuels instead of the sun's heat. So power can be made any time, day or night. Once perfected and manufactured on a large scale, this system has the potential to be one of the cheapest solar energy technologies available.

According to The American Heritage Dictionary of the English Language, the word "solar" originates from the Latin word sol, meaning sun.

Photo taken by Bill Timmerman.

power was used in the industrial revolution, when water was heated for use in machines as steam. Solar power's widespread use started in the 1930s but was cut short when gas and fossil fuels became cheaper and took over the market. The cost of solar power was high, and little interest was put into it until the 1960s and 1970s. Today solar arrays and solar concentrators are the focus of major studies for use in space and here on earth.

Sunlight is an excellent energy source, and the future of using solar power is very exciting. The Sun's energy can be used to heat and cool buildings, generate electricity, operate communication and navigation systems, and even power solar cars.

Solar-powered cars all get their fuel from the same place—the Sun. The cars use hundreds of photovoltaic cells to convert sunlight into electricity. Each cell produces about one-half volt of electricity. When the American Solar Challenge teams design their electrical systems, they have to allow for variations in sunlight. The Sun's energy powers the car's motor and charges a battery for use when the Sun is hidden by a cloud. If a car is designed to put all of its energy toward driving and keeps nothing in reserve, it will stop completely in cloudy weather. If too much energy is diverted to the battery, the engine runs too slowly to keep up in the race.

Engineers and scientists still have many questions and problems to tackle before solar power becomes an efficient and economical way to fuel vehicles. But as the demand on fossil fuel resources increases, research will continue to search for alternative energy sources, including harnessing the Sun's energy to drive a vehicle. The most exciting part of using solar power as an energy source is that it is pollution-free and inexhaustible.

In this case study, your team of three will design a solar racer and compete against other teams in your class. It is important that you first have knowledge in three key areas: aerodynamics, chassis development, and photovoltaics. These pre-competition lessons should be done in class before your team starts the design process. Complete CAD drawings and electronic presentations should be prepared prior to testing. Your team will be evaluated in the following areas:

1. Time to go 20 meters
2. Rolling resistance and aerodynamic drag
3. Total vehicle weight
4. Acceleration
5. Top speed

Resources

www.nrel.gov/education/student/natjss.html – U.S. Department of Energy's National Junior Solar Sprint, managed for the U.S. Department of Energy by National Renewable Energy Laboratory (NREL). This competition is intended for middle school students, but the program is so detailed and technical in nature that it can be used in the high school arena. Some of the vocabulary and "ways to accomplish" do need to be edited and reworded to the high school level so that the reading level is accurate.

www.formulasun.org/asc/index.html – The American Solar challenge is a student organization dedicated to educating students about solar electric vehicle design and construction by providing a hands-on environment in which students are encouraged to apply theories learned in the classroom.

Asimov, Isaac. (1981). *How Did We Find Out About Solar Power?* New York: Walker and Company.

Catherall, Ed. (1982). *Solar Power*. New Jersey: Silver Burdett Company.

Gadler, Steve & Adamson, Wendy W. (1980). *Sun Power Facts About Solar Energy*. Minneapolis, MN: Lerner Publications.

Electric Power Research Institute, Transportation Program Office, P.O. Box 10412, Palo Alto, CA 94303.

Sunrayce c/o General Motors, Attn: Bruce McCristal, GM Building, Detroit, MI 48202, (313) 556-2025.

U.S. Department of Energy Conservation and Renewable Energy, 1000 Independence Avenue, S.W., Washington, DC 20585.

Assessment

Solar Car Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Research	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demonstrating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	
Prototype	The Prototype and sketches are complete, with detail and relevant materials and labels.	The Prototype and sketches are complete, using relevant materials and labels.	The Prototype and sketches are complete, using relevant materials.	The Prototype and sketches are incomplete but use relevant materials.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disordered, or is confusing.	
CAD Drawings	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawing includes both device and host, with missing information or dimensions.	The drawings are incomplete, but an attempt was made.	
Time to Go 20 Meters	Top ten percent of class.	Top twenty percent of class.	Top thirty percent of class.	Forty percent and beyond.	
Rolling Resistance and Aerodynamic drag	Top ten percent of class.	Top twenty percent of class.	Top thirty percent of class.	Forty percent and beyond.	
Total Vehicle Weight	Top ten percent of class.	Top twenty percent of class.	Top thirty percent of class.	Forty percent and beyond.	
Acceleration	Top ten percent of class.	Top twenty percent of class.	Top thirty percent of class.	Forty percent and beyond.	
Top Speed	Top ten percent of class.	Top twenty percent of class.	Top thirty percent of class.	Forty percent and beyond.	

Fling It!

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *2-3 weeks*

Teacher Preparation

This case study will take ten to fifteen classroom days to complete. It is recommended that the instructor obtain the necessary calculations to complete this prototype and be proficient in their use. The objectives for this case study are:

1. To design a working model of a trebuchet and demonstrate the power of a Class 1 lever.
2. To determine the effectiveness of each trebuchet based on how far it will throw a water balloon.

Instructors should introduce students to these machines through lecture and viewing of videos on Medieval Siege Machines. The suggestion is that you obtain the NOVA video "Secrets of Lost Empires: Medieval Siege." There is a companion Web site to the video that has a lot of information that will help you and your students in the classroom. The Web site is listed in the resource section on page 88. Instructors should review simple machines with the class, specifically the three classes of levers. Teams of three should be randomly selected, using a deck of cards from which the students draw numbers. Each team will be responsible for documenting the process it went through. This can be through daily lab reports or a team journal. Detailed drawings and descriptions should be included. It is also suggested that the instructor be familiar with calculations that are associated with the case study and be proficient in their use.

There are also books and software programs that allow students to enter numbers and do calculations in order to plan for the length of the throw.

Case Study

The history of catapults goes back to medieval times. The Romans however, were the first group to make catapult design an "art of war." Catapults could be made to sling projectiles over 100 meters, but they could only be used a small number of times before the components (mostly oak wood) began to fatigue. A trebuchet is similar to a first-order lever, with the counterweight providing the effort and the projectile supplying the load. All this is on a fulcrum.

Your three-person team has been charged to design and build a mighty siege machine—called a trebuchet—that will fling a water balloon across a far distance. You

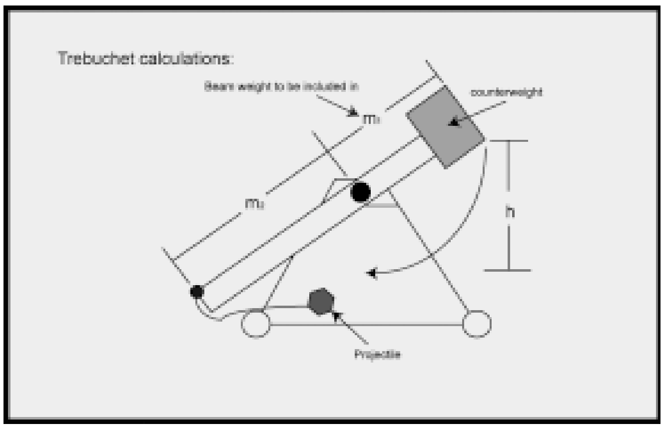
In celebration of Saint Barbara Day, patron saint of artillery, the Marines of the 11th Marine Regiment decided to take part in a rather strange, yet challenging, competition at Camp Pendleton. Marines from 3/11's survey section put the finishing touches on the bowling ball throwing catapult. With the throwing arm in its fully erect position, the trebuchet is 21 feet tall.

Photograph by Sgt. Ken Griffin.
Published with permission of the U.S. Marine Corps.

have been provided with some materials to build your trebuchet: You must use 2 x 4s, selected plywood scrap, wood screws, 1” black pipe for the axle, flat steel where needed, and twine. Your missile will be a water balloon. You will need to construct the following parts of a working trebuchet:

- Two triangular pieces for the sides of the frame; these will need to be supported or braced to stay upright. Parameters for base and height of fulcrum point will be: 2’ wide by 4’ long, fulcrum point shall be no higher than 3’.
- A long, throwing arm pierced by the axle; the short end of the throwing arm should have a small, heavy counterweight that will allow the throwing arm to swing freely without touching the sides of the frame or ground.
- A sling that will hold the water balloon during the upswing and release it at the top of the arc.

Your team is responsible for researching safety when using trebuchets as well. Make notes of any issues that are read about and be sure to include a section on safety in your final presentation. Each member of the teams should do individual research on catapults, trebuchets, and the systems associated with these machines.



m1 = the mass of the counterweight and beam (in Kg)

m2 = the mass of the projectile and beam (in Kg)

h = the distance that the counterweight falls (in meters)

1. Compute theoretical velocity of projectile:

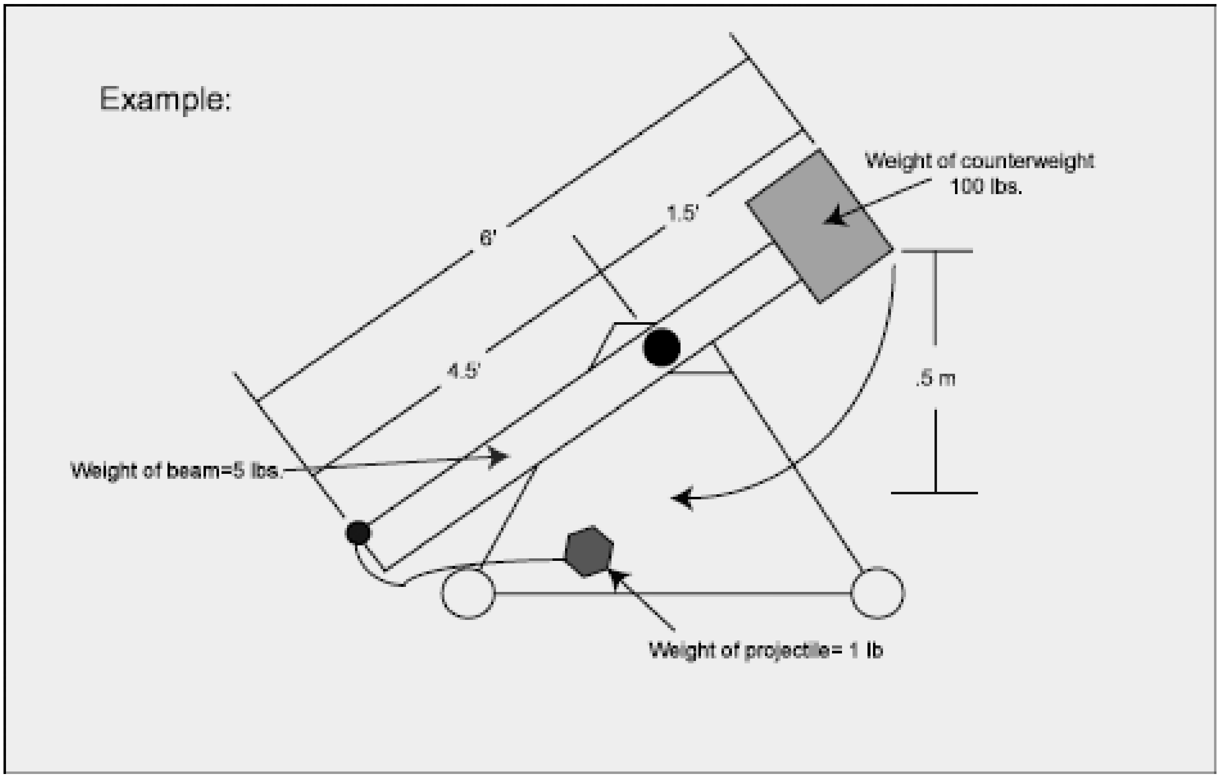
$$V_{Theo} = \sqrt{\frac{2(m)(g)(h)}{(m)^2}} \qquad g= 9.087m/s^2$$

2. Compute theoretical range of projectile:

$$R_{Theo} = \frac{(V_{Theo})^2}{g} \times \text{Sin } 2(\theta)$$

θ= the angle of elevation at which the projectile leaves the trebuchet

Here is one trebuchet and its calculations:



1. Compute theoretical velocity:

$$V_{Theo} = \sqrt{\frac{2(.567Kg + 45.359Kg)(9.087m/s^2)(.5m)}{(1.701Kg + .454Kg)}}$$

$$= \sqrt{\frac{450.396\,\frac{Kgm^2}{s^2}}{2.155\ Kg^2}} = \sqrt{209.001\ m/s} \quad =14.457m/s$$

2. Compute theoretical range:

$$R_{Theo} = \frac{(14.457\ m/s)^2}{9.087m/s^2} \times \text{Sin } 2(45^\circ) = \boxed{\text{21.311m or about 70 feet}}$$

Assessment

Fling It! Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Gantt Chart	The timeline is complete, with formatting tasks, dates, and persons assigned to tasks.	The timeline is complete, with formatting, tasks, and dates.	The timeline is complete, with tasks, dates.	The timeline is incomplete, but an effort was made.	
Calculations	The calculations are complete, with detail and relevant formulas and labels.	The calculations are complete, using relevant formulas and labels.	The calculations are complete, using relevant formulas.	The calculations are incomplete but use relevant formulas.	
CAD Drawings	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawing includes relevant information but is missing dimensions.	The drawings are incomplete, but an attempt was made.	
Cost Analysis	The cost analysis is complete and formatted, with pricing, sources, and total costs per item used.	The cost analysis is complete, with pricing, sources, and total costs per item used.	The cost analysis is complete, with pricing and total costs per item used.	The cost analysis is incomplete but has some pricing available.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information is included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disor-dered, or is confusing.	
Prototype	The Prototype and sketches are complete, with detail and relevant materials and labels.	The Prototype and sketches are complete, using relevant materials and labels.	The Prototype and sketches are complete, using relevant materials.	The Prototype and sketches are incomplete but use relevant materials.	
Design Proposal/ Research Report	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demon-strating a basic understanding of content and information.	Limited effort is made to under-stand content at a very simplistic level.	

Resources

www.glpbooks.com – Great Lakes Press Web site.

www.pbs.org/wgbh/nova/lostempires/trebuchet/ – The companion Web site to the NOVA program “Medieval Siege.” In the film, which is a part of the NOVA series Secrets of Lost Empires, a team of timber framers and other specialists design, build, and fire a pair of trebuchets, a devastating engine of war popular in the Middle Ages.

www.trebuchet.com/sim/ – The ATreb Simulator Program. You can add the effects of air drag and friction, do stress analysis on your arm, sling, pin, axle... and work out all the finer details of your trebuchet design before you even buy a single piece of lumber. It also includes a metric conversion calculator, release pin optimizer, and you can save hundreds of design parameters and simply load them from disk to work on different projects at the click of a button.

Case study reprinted from “Engineering Your Future, A Project-Based Approach” with the permission of Great Lakes Press, Inc., PO Box 550, Wildwood, MO 63040-0550.

Special thanks to Mr. Vern Jordan and Mr. Johnson at Fort Atkinson High School in Fort Atkinson, Wisconsin for the initial design and testing of this case study.

Project "RECYCLE"

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *2-3 weeks*

Teacher Preparation

This case study will take five to fifteen classroom days to complete. It is to be noted that the playing field must be constructed by the instructor in a timely fashion in order to allow preliminary testing. Two or three testing fields may be necessary depending on the number of students in your class. Cost is a contributing factor as is whether the instructor or the class as a whole should determine a maximum cost for the prototype. Objects needed for the construction of prototypes will be determined by students after the brainstorming and final design processes are complete.

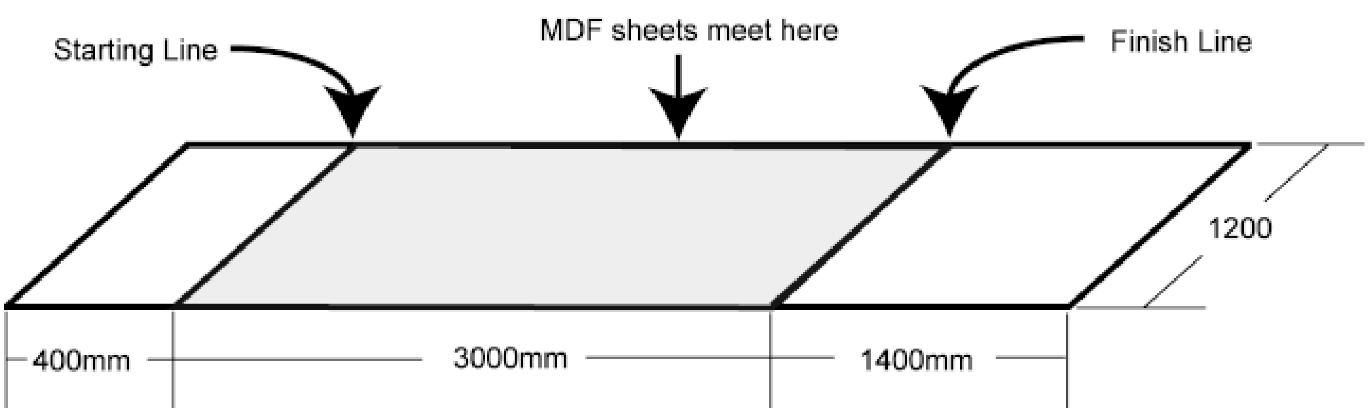
Case Study

For many years, teams of mechanical engineering students have visited the distant planet of Gondwana to gain valuable work experience. On each occasion they have been able to apply their knowledge and skill to devise ingenious solutions to help the Gondwanans develop their planet. Over the years, these students have been explaining to the Gondwanans the benefit of recycling as a means of conserving resources, even on an underdeveloped planet like Gondwana.

Consequently, this year the Gondwanans have asked the students to develop prototype machinery for recycling Ylem compounds, which are found in limited quantity on the planet and have valuable properties in many of their industrial processes. The material must be moved in relatively small batches from a community collection point because larger quantities develop spontaneous reactions that destroy the material. It must be moved across an open, level area (and must be kept away from this surface to avoid pollution) and placed in the elevated intake hopper of the re-processing plant. The higher the hopper can be made, the greater will be the efficiency of the recycling process. Economical design of the equipment is important in order to conserve scarce construction materials and to limit ground pressure on the potentially unstable surface of the planet.

Can your team of three design and build a lightweight device that combines speed and lift in order to make the recycling process work as efficiently as possible? (Recycling and Energy Conservation of Ylem Compounds using Lightweight Equipment.)

Teams of three engineering students are required for the competition. Each team may enter one device only. Resources on Gondwana are limited, and so the students must manufacture their device themselves, using commonly available materials and components. The competition site will consist of two horizontal sheets of 2400 x 1200 x 19 mm Medium Density Fiberboard (MDF), joined together and arranged end-to-end. A starting line will be drawn across one sheet, 400 mm from the free end. A finishing line will be drawn across the second sheet, 3000 mm from, and parallel to, the starting line. All surfaces of the MDF sheets will be treated with one to two coats of Urethane sealer.



1. Prior to a run, the team must calculate the mass of dry, white, “Minute” brand medium grain rice, representing the Ylem to be recycled (to a maximum of 5 kg), and load this into a hand-held receptacle supplied by the team. This receptacle is not part of the device and cannot be carried on or with the device during the run.
2. Prior to its release, the device may have maximum plan dimensions of 300 x 300 mm, a maximum height of 500 mm, and its mass must not exceed 5 kg. The device must be placed entirely behind the starting line and set up ready for a run within two minutes of a request to do so. The Ylem must be loaded into the container in the device during this two-minute period.
3. At the signal to start, one team member must release the device by a single action that does not impart motion to the device.
4. The run finishes when the device is stationary on the competition site beyond the finishing line and the Ylem is elevated to its delivery height. The run must be completed within two minutes. The Ylem must remain elevated for one minute or, at the judges’ sole discretion, for a lesser time. **For a run to be valid, at least 100 g of Ylem must be successfully transported.**
5. After the device is released, it may not come into contact with anything other than the upper surface of the competition site, and its motion may not be influenced by any person.
6. Any spillage of Ylem will incur a 20-second time penalty.
7. Each team will attempt two runs, and the Competition Score will be the average of the scores from these two runs. The device may be modified between runs.
8. In the case of a tie for first place, there shall be repeated head-to-head runs between these teams until only one team remains. These repeated runs will be conducted at five-minute intervals.
9. Devices that are deemed by the judges to be hazardous will not be permitted to run. In particular, devices using combustion or which damage the site are prohibited.
10. The judges’ decisions on all matters pertaining to the competition will be final.
11. **Lighter-than-air gases (e.g. hydrogen, helium) may not be used in the device.**

The score for a run will be computed from the equation:
Score (%) = $[(2H / H_{max}) + (R / R_{max}) + (W_{min} / W)] \times 100/4$

H = Hopper delivery height of Ylem in the device, measured from the site surface to the lowest part of the container holding the Ylem (in mm). The lowest part of the container holding the Ylem must be accessible at the completion of a run to allow this measurement.

R = Mass transport rate achieved (grams/second) = M/t

Where

M = Mass of Ylem successfully transported (in grams). On instruction from the judges, the students will be required to transfer (by any means) the Ylem from their device container to their receptacle to allow M to be determined.

and

t = total transit time from start to finish (in seconds).

W = The tare weight of the vehicle (in grams).

R_{max} = The maximum mass transport rate achieved by all competitors during the current session.

H_{max} = The maximum hopper delivery height achieved by all competitors during the current session.

W_{min} = The minimum tare weight achieved by all competitors during the current session.

Assessment

Project "RECYCLE" Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Gantt Chart	The timeline is complete, with formatting tasks, dates, and persons assigned to tasks.	The timeline is complete, with formatting, tasks, and dates.	The timeline is complete, with tasks, dates.	The timeline is incomplete, but an effort was made.	
CAD Drawings	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawing includes both device and host, with missing information or dimensions.	The drawings are incomplete, but an attempt was made.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information is included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disor-dered, or is confusing.	
Design Proposal/ Research Report	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demon-strating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	
Prototype	The Prototype and sketches are complete, with detail and relevant materials and labels.	The Prototype and sketches are complete, using relevant materials and labels.	The Prototype and sketches are complete, using relevant materials.	The Prototype and sketches are incomplete, but use relevant materials.	
Average Scoring from Qualifying Runs. Percentage earned multiplied by possible points (60)	→	→	→	→	

Resources

www.ncedaust.org – National Committee On Engineering Design (NCED). (2001). Warman Design-and-Build Competition. In 1988, the Panel on Engineering Design in Australia initiated a national "design-and-build" competition, known today as the Warman Design-and-Build Competition.

Project "RECYCLE" was originally devised and run as the 2001 Warman Student Design-and-Build Competition for second-year students in Mechanical Engineering courses in Australian Universities. The Competition has been run annually since 1988 by the National Committee on Engineering Design (part of the Mechanical College of Engineers Australia) with sponsorship from Warman International, now known as Weir Warman Limited. Further details of the Warman Competition may be obtained from www.ncedaust.org.

Content: *Nature and development of technology, Technological progress, Rate of technological development*
Time: *2-3 weeks*

Teacher Preparation

This case study will take between 10 and 15 classroom days to complete. It is recommended that the instructor be trained in heat loss and air infiltration heat loss calculations before he or she attempts this case study. It is important to have all materials on site for the completion of the case study. If a full-scale prototype will be made, select the best wall section and the best design from the presentation and re-develop the solution to create only one prototype. It is feasible to build multiple prototypes; however, this is very time- and space-consuming.

Case Study

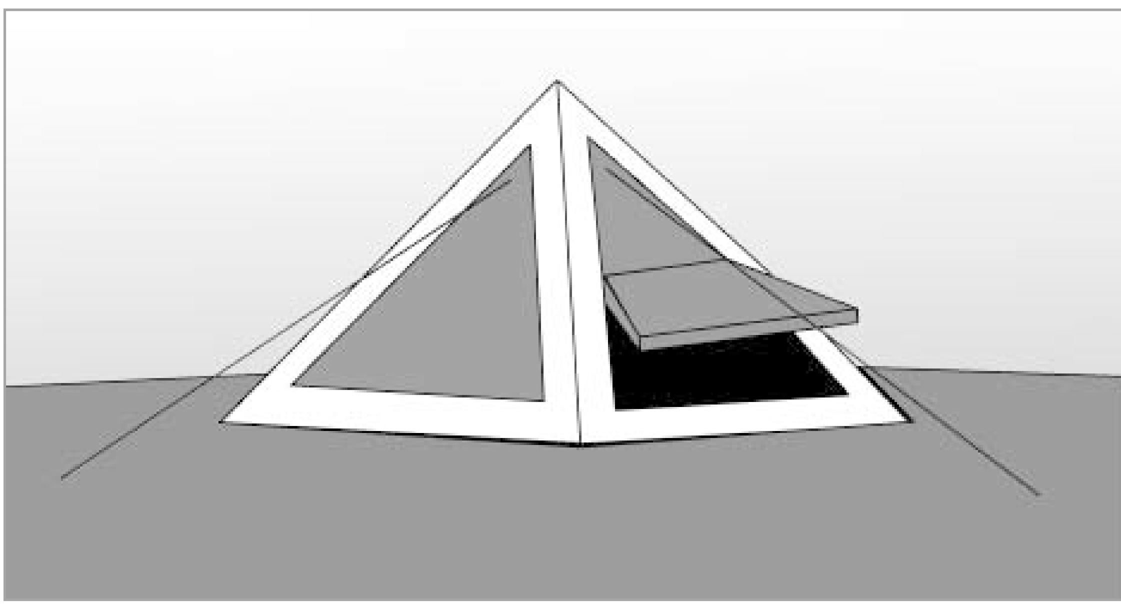
One of the most significant problems in metropolitan cities today is homeless people. During the cold winter months of the northern Midwest, outside temperatures can reach 60 degrees Fahrenheit below zero. It is not surprising that, if humans are outside with no protection, they will perish. On a smaller scale, yet equally critical, is when people are stranded in an area from which they cannot be recovered or rescued via airlift, etc. A viable temporary solution to this problem would be to drop a structure in which they could survive for a few days until a ground rescue team could reach them.

Your team of three students has been selected to design a shelter in which people can survive in cold weather. The people who are going to use the shelter must keep the shelter heated with nothing other than their own body heat. Two of the most important things your team must keep in mind are:

1. Ensure that the heat generated by the people is retained and too much heat does not escape the shelter.
2. Ensure that there is enough air circulating so that the people do not suffocate.

This case study will involve the use of many problem-solving methods. It will be important to work as a team and assign members specific jobs to do. The rules for the shelter development are listed on page 93. These must be followed by every team. These rules are part of a Request For Proposal, or an RFP, which is how companies, the government, and other agencies outline their project needs.

"An RFP in its most formal sense is a specification of requirements that is sent out to suppliers who reply with proposals. Although common with large companies, the idea can be usefully applied at varying levels of sophistication to small and medium organizations as well. Used properly, it is a tool that supports and protects the buyer." (Lilley Information Systems)



This is a sample rendering of a shelter. This is not one of the required elements in the assessment; however, it is a good tool to aid in a formal presentation.

RFP

To: Engineering teams of three

Subject: Request For Proposals

Project: Shelter, portable, Homeless/Emergency supply, cold weather type

Agency: Anytown, USA Disaster Agency

Project Description: Design a low-cost structure made out of 90% cardboard that will allow people to survive outside during very cold weather. Because it is made of cardboard it will be biodegradable in nature.

1. Shelter capacity – Protect five people for a period of up to three days.
2. Construction materials – Standard 1/8” corrugated cardboard in multiple layers as needed, plus any additional materials for insulation, waterproofing, and protection. Other hardware as required for fastening, anchoring, packaging, etc.
3. Inside temperature is to be kept at exactly 60 degrees Fahrenheit when the outside temperature is 20 degrees below zero Fahrenheit.
4. The shelter must be able to be dropped and survive without significant damage from a height of 200 feet. Note: The shelter will be tested for this requirement only after the temperature testing is complete.
5. The shelter must be assembled in less than 15 minutes and without any tools.
6. The instructions for the shelter assembly must be in pictograms or “cartoon” format so that language is not a problem for people.
7. To minimize cost of an individual shelter, ideally the shelter would have an exterior surface area of 120 square feet or less. The thickness of the wall should not exceed five inches.
8. The shelter must allow proper ventilation to allow all five people to breathe.
9. The shelter (when empty) must be held down to the ground so it does not blow away with gusts of wind up to 25 miles per hour.

The structure must be able to withstand two feet of wet snow.

Resources

www.glpbooks.com – Great Lakes Press Web site.

Case study reprinted from “Engineering Your Future, A Project-Based Approach” with the permission of Great Lakes Press, Inc., PO Box 550, Wildwood, MO 63040-0550.

Mull, Thomas E. (1997). *HVAC Principles and Applications Manual*. The McGraw-Hill Companies, Publisher. ISBN: 007044451X.
An on-the-job handbook for beginning or experienced engineers, providing information on design, applications, and code compliance without delving into theory and complex mathematics. Includes such topics as basic scientific principles, climatic conditions, infiltration and ventilation, external heat gains and cooling loads, acoustics and vibrations, human comfort, fans and central air systems, an introduction to electrical systems, and controls for air distribution systems. Appendices contain tables of technical matter such as the thermal properties of building materials and the average winter temperature for major U.S. cities.

www.lilleyinfosys.co.uk/ – Lilley Information Systems is an independent Information Systems consultancy. Established in 1980, they are based in London, UK. In addition to their systems work they also carry out PR (Public Relations).

Assessment

Emergency/Homeless Shelter Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Gantt Chart	The timeline is complete, with formatting tasks, dates, and persons assigned to tasks.	The timeline is complete, with formatting, tasks, and dates.	The timeline is complete, with tasks and dates.	The timeline is incomplete, but an effort was made.	
Calculations	The calculations are complete, with detail and relevant formulas and labels.	The calculations are complete, using relevant formulas and labels.	The calculations are complete, using relevant formulas.	The calculations are incomplete but use relevant formulas.	
CAD Drawings	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawing includes relevant information but is missing dimensions.	The drawings are incomplete, but an attempt was made.	
Cost Analysis	The cost analysis is complete and formatted, with pricing, sources, and total costs per item used.	The cost analysis is complete, with pricing, sources, and total costs per item used.	The cost analysis is complete, with pricing and total costs per item used.	The cost analysis is incomplete but has some pricing available.	
Pictograms	The pictograms accurately describe the instructions and are easy to read without language or numbers.	The pictograms accurately describe the instructions and are without language or numbers.	The pictograms accurately describe the instructions but include language or numbers.	The pictograms provide an overview of the instructions but are incomplete.	
Ergonomic Layout	The ergonomic layout and use of the prototype is clearly formatted, including alternative uses.	The ergonomic layout and use of the prototype is clearly formatted.	The ergonomic layout and use of the prototype is available but has uncertainty to its use.	The ergonomic layout is available but is incomplete.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information is included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disor-dered, or is confusing.	
Scale Models	The scale models are complete, with detail and relevant materials and labels.	The Scale models are complete, using relevant materials and labels.	The Scale models are missing information or dimensions.	The Scale models are incomplete, but an attempt was made.	
Design Proposal/ Research Report	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demon-strating a basic understanding of content and information.	Limited effort is made to under-stand content at a very simplistic level.	

The Walker

Content: *Nature and development of technology, Technological progress, Rate of technological development*

Time: *3-5 weeks*

Teacher Preparation

Teachers will need to prepare for this long case study by first contacting an organization or group of people that would allow students to come in and speak with them about their needs regarding walkers. A good place to start is a local nursing home or retirement home. It may be a stretch to go to a hospital, as usually the patients are being cared for. Ergonomics are a large portion of this case study, and students should be exposed to as much information on this topic as possible before beginning the case study. Local suppliers may be able to help supply the materials needed to produce the prototypes depending on the designs of the students. Typically, the walkers will be fabricated using lightweight metals, and a review of welding fundamentals may be necessary. Working prototypes can fail during use, so be careful to observe and check over a group's prototype and test within the class before taking it into the community.

Data and research should be presented within a written and oral report that is given at the end of the case study. It is important to note that a marketing plan for the product will also have to be turned in by the students. Please exercise caution with testing prototypes as they may fail during use. Finite element analysis software, like Cosmos Works, can help in determining if a design will succeed or fail.

Case Study

Walkers are used by many people in the community to help them in their daily routines. These walkers are used indoors and outdoors. When they are used outdoors, it can be in treacherous downpours of rain in Seattle, in the sweltering heat of the Arizona desert, or during blowing snowstorms in the Midwest. In any environment, a walker must assist the user, while not adding any danger because of environmental conditions.

A walker must be lightweight, yet sturdy enough to support even a 300-pound person. These walkers have to be configurable to a range of different heights and body types as well. A walker is used not just for guidance while walking but for storage of items that may be taken along for the trip. Elderly people do their shopping with walkers, bring home leftovers from lunch, and carry items to and from their homes while depending upon these devices for stability. Some medical conditions dictate that users of walkers also carry with them equipment to support life functions. Whether it be an external tank for oxygen supply or a shoulder strap battery for heart functions, clearly walkers must be able to assist in carrying these types of devices.

Many walkers incorporate braking systems; however, usually these systems are bicycle systems that are simply retrofitted to the walkers and can actually hurt the performance and ability of the walker to stabilize the user. When the user has more strength in one hand than the other, the walker will brake harder on one side than the other, causing steering and stability issues. If a user has similar strength in both hands, this same issue can occur when the braking system is out of adjustment. Any new braking system designed must account for these inefficiencies.

Your team of three is assigned to research, develop, model, test, collect data, and actually build a prototype for the walker your team designs. This may include surveying the elderly for their wants and needs or visiting a hospital or nursing home to observe the use of walkers. Your team will build a prototype that can be tested by people. A word of caution on this case study: Do not test these prototypes with persons who need assistance with walking or may be uncoordinated. The testing should be in a simulated setting with your peers or people in your community. Your instructor will help supply your team with the needed materials and fabrication methods after the design is researched and determined.

The Walker Rubric

Category	Exemplary 30-24	Accomplished 18	Developing 12	Beginning 6	Score
Gantt Chart	The timeline is complete, with formatting tasks, dates, and persons assigned to tasks.	The timeline is complete, with formatting, tasks, and dates.	The timeline is complete, with tasks, dates.	The timeline is incomplete, but an effort was made.	
Research Data	Data is clearly laid out, with examples including personal interviews, statistical analysis, and hypothesis created.	Data is clearly laid out, with examples including personal interviews, statistical analysis, but no hypothesis.	Data is laid out and statistical analysis is complete.	Data is incomplete and statistical analysis is incomplete; some examples are present.	
Calculations	The calculations are complete, with detail and relevant formulas and labels.	The calculations are complete, using relevant formulas and labels.	The calculations are complete, using relevant formulas.	The calculations are incomplete, but use relevant formulas.	
CAD Drawings	The drawings are complete, with detail and relevant materials and labels.	The drawings are complete, using relevant materials and labels.	The drawing includes relevant information but is missing dimensions.	The drawings are incomplete, but an attempt was made.	
Cost Analysis	The cost analysis is complete and formatted, with pricing, sources, and total costs per item.	The cost analysis is complete, with pricing, sources, and total costs per item used.	The cost analysis is complete, with pricing and total costs per item used.	The cost analysis is incomplete but has some pricing available.	
Electronic Presentation	Presents easy-to-follow information that is logical and adequately detailed. All graphics and supplemental information included.	Most of the information is included. All graphics and supplemental information is included.	Most of the information is included. No graphics or supplemental information included.	Most of the information is missing, disor-dered, or is confusing.	
Prototype	The Prototype and sketches are complete, with detail and relevant materials and labels.	The Prototype and sketches are complete, using relevant materials and labels.	The Prototype and sketches are complete, using relevant materials.	The Prototype and sketches are incomplete but use relevant materials.	
Design Proposal/ Research Report	Information is well organized, with ideas and details added to give meaning.	Information is well organized, and an attempt is made to add meaning.	Student is demon-strating a basic understanding of content and information.	Limited effort is made to understand content at a very simplistic level.	

Resources

www.tracecenter.org/ – The Trace Research & Development Center is a part of the College of Engineering, University of Wisconsin-Madison. Founded in 1971, Trace has been a pioneer in the field of technology and disability.

Trace Center Mission Statement: To prevent the barriers and capitalize on the opportunities presented by current and emerging information and telecommunication technologies, in order to create a world that is as accessible and usable as possible for as many people as possible.

A few examples of manufacturers or resellers of handicapped walkers:
www.allegromedical.com
www.scooterdepot.com/walkers.htm

Academic Connections – Unit 5

Mathematics

- Develop a deeper understanding of very large and very small numbers and of various representations of them.
- Develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases, and technology for more complicated cases.
- Judge the reasonableness of numerical computations and their results.
- Analyze properties and determine attributes of two- and three-dimensional objects.
- Explore relationships (including congruence and similarity) among classes of two- and three-dimensional geometric objects, make and test conjectures about them, and solve problems involving them.
- Use trigonometric relationships to determine lengths and angle measures.
- Use Cartesian coordinates and other coordinate systems, such as navigational, polar, or spherical systems, to analyze geometric situations.
- Investigate conjectures and solve problems involving two- and three-dimensional objects represented with Cartesian coordinates.
- Understand and represent translations, reflections, rotations, and dilations of objects in the plane by using sketches, coordinates, vectors, function notation, and matrices.
- Draw and construct representations of two- and three-dimensional geographic objects using a variety of tools.
- Visualize three-dimensional objects and spaces from different perspectives and analyze their cross sections.
- Use geometric models to gain insights into, and answer questions in, other areas of mathematics.
- Use geometric ideas to solve problems in, and gain insights into, other disciplines and other areas of interest such as art and architecture.
- Make decisions about units and scales that are appropriate for problem situations involving measurement.
- Analyze precision, accuracy, and approximate error in measurement situations.
- Understand and use formulas for area, surface area, and volume of geometric figures, including cones, spheres, and cylinders.
- Apply informal concepts of successive approximation, upper and lower bounds, and limit in measurement situations.
- Solve problems that arise in mathematics and in other contexts.
- Communicate mathematical thinking coherently and clearly to peers, teachers, and others.
- Recognize and apply mathematics in contexts outside of mathematics.
- Use representations to model and interpret physical, social, and mathematical phenomena.

Science

- Identify questions and concepts that guide scientific investigations.
- Design and conduct scientific investigations.
- Use technology and mathematics to improve investigations and communications.
- Recognize and analyze alternative explanations and models.
- Evidence and reasoning in inquiry.
- Ratios and proportionality.
- Describing change.

- Averages and comparisons.
- Correlation.
- Statistical reasoning.
- Energy in the earth system.
- Geo-chemical cycles.
- Design constraints.
- Designed systems.
- Identify a problem or design an opportunity.
- Propose designs and choose between alternative solutions.
- Implement a proposed solution.
- Evaluate the solution and its consequences.
- Communicate the problem, process, and solution.
- Understandings about science and technology.
- Decisions about using technology.
- Culture affects behavior.
- Population growth.
- Natural resources.
- Environmental quality.
- Natural and human-induced hazards.
- Science and technology in local, national, and global challenges.
- Science as a human endeavor.
- Influences of social change.

English

- *Lab reports*
  Students will link their English writing skills with this course through lab reports. The students should use complete sentences to describe their thoughts and activities.
- *Documentation*
  Technical data and information is recorded as part of the activities.
- *Essays*
  These should be used as a tool to summarize and synthesize research. These may be given as individual assignments or could be included as part of a larger assignment. Teachers should develop grading criteria and inform the students before the essay is started.

Chapter 3

Appendix

Chapter 3 – Appendix A

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Chapter 3 – Appendix B

Listing of Technology Content Standards in Standards for Technological Literacy

The Nature of Technology

Standard 1. Students will develop an understanding of the characteristics and scope of technology.

Grade Level		Benchmarks: *In order to comprehend the scope of technology, students should learn that:*
K-2	A.	The natural world and human-made world are different.
	B.	All people use tools and techniques to help them do things.
3-5	C.	Things that are found in nature differ from things that are human-made in how they are produced and used.
	D.	Tools, materials, and skills are used to make things and carry out tasks.
	E.	Creative thinking and economic and cultural influences shape technological development.
6-8	F.	New products and systems can be developed to solve problems or to help do things that could not be done without the help of technology.
	G.	The development of technology is a human activity and is the result of individual and collective needs and the ability to be creative.
	H.	Technology is closely linked to creativity, which has resulted in innovation.
	I.	Corporations can often create demand for a product by bringing it onto the market and advertising it.
9-12	J.	The nature and development of technological knowledge and processes are functions of the setting.
	K.	The rate of technological development and diffusion is increasing rapidly.
	L.	Inventions and innovations are the results of specific, goal-directed research.
	M.	Most development of technologies these days is driven by the profit motive and the market.

Standard 2. Students will develop an understanding of the core concepts of technology.

Grade Level		Benchmarks: *In order to comprehend the core concepts of technology, students should learn that:*
K-2	A.	Some systems are found in nature, and some are made by humans.
	B.	Systems have parts or components that work together to accomplish a goal.
	C.	Tools are simple objects that help humans complete tasks.
	D.	Different materials are used in making things.
	E.	People plan in order to get things done.
3-5	F.	A subsystem is a system that operates as a part of another system.
	G.	When parts of a system are missing, it may not work as planned.
	H.	Resources are the things needed to get a job done, such as tools and machines, materials, information, energy, people, capital, and time.
	I.	Tools are used to design, make, use, and assess technology.
	J.	Materials have many different properties.
	K.	Tools and machines extend human capabilities, such as holding, lifting, carrying, fastening, separating, and computing.
	L.	Requirements are the limits to designing or making a product or system.
6-8	M.	Technological systems include input, processes, output, and, at times, feedback.
	N.	Systems thinking involves considering how every part relates to others.
	O.	An open-loop system has no feedback path and requires human intervention, while a closed-loop system uses feedback.
	P.	Technological systems can be connected to one another.
	Q.	Malfunctions of any part of a system may affect the function and quality of the system.
	R.	Requirements are the parameters placed on the development of a product or system.
	S.	Trade-off is a decision process recognizing the need for careful compromises among competing factors.
	T.	Different technologies involve different sets of processes.
	U.	Maintenance is the process of inspecting and servicing a product or system on a regular basis in order for it to continue functioning properly, to extend its life, or to upgrade its quality.

Standard 2, cont.

Grade Level		Benchmark
	V.	Controls are mechanisms or particular steps that people perform using information about the system that causes systems to change.
9-12	W.	Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.
	X.	Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.
	Y.	The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.
	Z.	Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.
	AA.	Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.
	BB.	Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.
	CC.	New technologies create new processes.
	DD.	Quality control is a planned process to ensure that a product, service, or system meets established criteria.
	EE.	Management is the process of planning, organizing, and controlling work.
	FF.	Complex systems have many layers of controls and feedback loops to provide information.

Standard 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Grade Level	Benchmarks: *In order to appreciate the relationships among technologies as well as with other fields of study, students should learn that:*	
K-2	A.	The study of technology uses many of the same ideas and skills as other subjects.
3-5	B.	Technologies are often combined.
	C.	Various relationships exist between technology and other fields of study.
6-8	D.	Technological systems often interact with one another.
	E.	A product, system, or environment developed for one setting may be applied to another setting.
	F.	Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.
9-12	G.	Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.
	H.	Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields.
	I.	Technological ideas are sometimes protected through the process of patenting.
	J.	Technological progress promotes the advancement of science and mathematics.

Technology and Society

Standard 4. Students will develop an understanding of the cultural, social, economic, and political effects of technology.

Grade Level	Benchmarks: *In order to recognize the changes in society caused by the use of technology, students should learn that:*	
K-2	A.	The use of tools and machines can be helpful or harmful.
3-5	B.	When using technology, results can be good or bad.
	C.	The use of technology can have unintended consequences.
6-8	D.	The use of technology affects humans in various ways, including their safety, comfort, choices, and attitudes about technology's development and use.
	E.	Technology, by itself, is neither good nor bad, but decisions about the use of products and systems can result in desirable or undesirable consequences.
	F.	The development and use of technology poses ethical issues.
	G.	Economic, political, and cultural issues are influenced by the development and use of technology.
9-12	H.	Changes caused by the use of technology can range from gradual to rapid and from subtle to obvious.
	I.	Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.
	J.	Ethical considerations are important in the development, selection, and use of technologies.

Standard 4, cont.

K. The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees.

Standard 5. Students will develop an understanding of the effects of technology on the environment.

Grade Level **Benchmarks:** *In order to discern the effects of technology on the environment, students should learn that:*

Grade Level		Benchmark
K-2	A.	Some materials can be reused and/or recycled.
3-5	B.	Waste must be appropriately recycled or disposed of to prevent unnecessary harm to the environment.
	C.	The use of technology affects the environment in good and bad ways.
6-8	D.	The management of waste produced by technological systems is an important societal issue.
	E.	Technologies can be used to repair damage caused by natural disasters and to break down waste from the use of various products and systems.
	F.	Decisions to develop and use technologies often put environmental and economic concerns in direct competition with one another.
9-12	G.	Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing, and recycling.
	H.	When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.
	I.	With the aid of technology, various aspects of the environment can be monitored to provide information for decision making.
	J.	The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment.
	K.	Humans devise technologies to reduce the negative consequences of other technologies.
	L.	Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.

Standard 6. Students will develop an understanding of the role of society in the development and use of technology.

Grade Level **Benchmarks:** *In order to realize the impact of society on technology, students should learn that:*

Grade Level		Benchmark
K-2	A.	Products are made to meet individual needs and wants.
3-5	B.	Because people's needs and wants change, new technologies are developed, and old ones are improved to meet those changes.
	C.	Individual, family, community, and economic concerns may expand or limit the development of technologies.
6-8	D.	Throughout history, new technologies have resulted from the demands, values, and interests of individuals, businesses, industries, and societies.
	E.	The use of inventions and innovations has led to changes in society and the creation of new needs and wants.
	F.	Social and cultural priorities and values are reflected in technological devices.
	G.	Meeting societal expectations is the driving force behind the acceptance and use of products and systems.
9-12	H.	Different cultures develop their own technologies to satisfy their individual and shared needs, wants, and values.
	I.	The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.
	J.	A number of different factors, such as advertising, the strength of the economy, the goals of a company, and the latest fads contribute to shaping the design of and demand for various technologies.

Standard 7. Students will develop an understanding of the influence of technology on history.

Grade Level **Benchmarks:** *In order to be aware of the history of technology, students should learn that:*

Grade Level		Benchmark
K-2	A.	The way people live and work has changed throughout history because of technology.
3-5	B.	People have made tools to provide food, to make clothing, and to protect themselves.
6-8	C.	Many inventions and innovations have evolved by using slow and methodical processes of tests and refinements.
	D.	The specialization of function has been at the heart of many technological improvements.
	E.	The design and construction of structures for service or convenience have evolved from the development of techniques for measurement, controlling systems, and the understanding of spatial relationships.

Standard 7, cont.

Grade Level		
	F.	In the past, an invention or innovation was not usually developed with the knowledge of science.
9-12	G.	Most technological development has been evolutionary, the result of a series of refinements to a basic invention.
	H.	The evolution of civilization has been directly affected by, and has in turn affected, the development and use of tools and materials.
	I.	Throughout history, technology has been a powerful force in reshaping the social, cultural, political, and economic landscape.
	J.	Early in the history of technology, the development of many tools and machines was based not on scientific knowledge but on technological know-how.
	K.	The Iron Age was defined by the use of iron and steel as the primary materials for tools.
	L.	The Middle Ages saw the development of many technological devices that produced long-lasting effects on technology and society.
	M.	The Renaissance, a time of rebirth of the arts and humanities, was also an important development in the history of technology.
	N.	The Industrial Revolution saw the development of continuous manufacturing, sophisticated transportation and communication systems, advanced construction practices, and improved education and leisure time.
	O.	The Information Age places emphasis on the processing and exchange of information.

Design

Standard 8. Students will develop an understanding of the attributes of design.

Grade Level	Benchmarks: *In order to comprehend the attributes of design, students should learn that:*	
K-2	A.	Everyone can design solutions to a problem.
	B.	Design is a creative process.
3-5	C.	The design process is a purposeful method of planning practical solutions to problems.
	D.	Requirements for a design include such factors as the desired elements and features of a product or system or the limits that are placed on the design.
6-8	E.	Design is a creative planning process that leads to useful products and systems.
	F.	There is no perfect design.
	G.	Requirements for design are made up of criteria and constraints.
9-12	H.	The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.
	I.	Design problems are seldom presented in a clearly defined form.
	J.	The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
	K.	Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 9. Students will develop an understanding of engineering design.

Grade Level	Benchmarks: *In order to comprehend engineering design, students should learn that:*	
K-2	A.	The engineering design process includes identifying a problem, looking for ideas, developing solutions, and sharing solutions with others.
	B.	Expressing ideas to others verbally and through sketches and models is an important part of the design process.
3-5	C.	The engineering design process involves defining a problem, generating ideas, selecting a solution, testing the solution(s), making the item, evaluating it, and presenting the results.
	D.	When designing an object, it is important to be creative and consider all ideas.
	E.	Models are used to communicate and test design ideas and processes.
6-8	F.	Design involves a set of steps, which can be performed in different sequences and repeated as needed.
	G.	Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.
	H.	Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.
9-12	I.	Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.
	J.	Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.
	K.	A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.

Standard 9, cont.

L. The process of engineering design takes into account a number of factors.

Standard 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Grade Level		**Benchmarks:** *In order be able to comprehend other problem-solving approaches, students should learn that:*
K-2	A.	Asking questions and making observations helps a person to figure out how things work.
	B.	All products and systems are subject to failure. Many products and systems, however, can be fixed.
3-5	C.	Troubleshooting is a way of finding out why something does not work so that it can be fixed.
	D.	Invention and innovation are creative ways to turn ideas into real things.
	E.	The process of experimentation, which is common in science, can also be used to solve technological problems.
6-8	F.	Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system.
	G.	Invention is a process of turning ideas and imagination into devices and systems. Innovation is the process of modifying an existing product or system to improve it.
	H.	Some technological problems are best solved through experimentation.
9-12	I.	Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.
	J.	Technological problems must be researched before they can be solved.
	K.	Not all problems are technological, and not every problem can be solved using technology.
	L.	Many technological problems require a multidisciplinary approach.

Abilities for a Technological World

Standard 11. Students will develop the abilities to apply the design process.

Grade Level		**Benchmarks:** *As part of learning how to apply design processes, students should be able to:*
K-2	A.	Brainstorm people's needs and wants and pick some problems that can be solved through the design process.
	B.	Build or construct an object using the design process.
	C.	Investigate how things are made and how they can be improved.
3-5	D.	Identify and collect information about everyday problems that can be solved by technology, and generate ideas and requirements for solving a problem.
	E.	The process of designing involves presenting some possible solutions in visual form and then selecting the best solution(s) from many.
	F.	Test and evaluate the solutions for the design problem.
	G.	Improve the design solutions.
6-8	H.	Apply a design process to solve problems in and beyond the laboratory-classroom.
	I.	Specify criteria and constraints for the design.
	J.	Make two-dimensional and three-dimensional representations of the designed solution.
	K.	Test and evaluate the design in relation to pre-established requirements, such as criteria and constraints, and refine as needed.
	L.	Make a product or system and document the solution.
9-12	M.	Identify the design problem to solve and decide whether or not to address it.
	N.	Identify criteria and constraints and determine how these will affect the design process.
	O.	Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.
	P.	Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
	Q.	Develop and produce a product or system using a design process.
	R.	Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.

Standard 12. Students will develop the abilities to use and maintain technological products and systems.

Grade Level	Benchmarks: *As part of learning how to use and maintain technological products and systems, students should be able to:*
K-2	A. Discover how things work.
	B. Use hand tools correctly and safely and name them correctly.
	C. Recognize and use everyday symbols.
3-5	D. Follow step-by-step directions to assemble a product.
	E. Select and safely use tools, products, and systems for specific tasks.
	F. Use computers to access and organize information.
	G. Use common symbols, such as numbers and words, to communicate key ideas.
6-8	H. Use information provided in manuals, protocols, or by experienced people to see and understand how things work.
	I. Use tools, materials, and machines safely to diagnose, adjust, and repair systems.
	J. Use computers and calculators in various applications.
	K. Operate and maintain systems in order to achieve a given purpose.
9-12	L. Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.
	M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.
	N. Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
	O. Operate systems so that they function in the way they were designed.
	P. Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.

Standard 13. Students will develop the abilities to assess the impact of products and systems.

Grade Level	Benchmarks: *As part of learning how to assess the impact of products and systems, students should be able to:*
K-2	A. Collect information about everyday products and systems by asking questions.
	B. Determine if the human use of a product or system creates positive or negative results.
3-5	C. Compare, contrast, and classify collected information in order to identify patterns.
	D. Investigate and assess the influence of a specific technology on the individual, family, community, and environment.
	E. Examine the trade-offs of using a product or system and decide when it could be used.
6-8	F. Design and use instruments to gather data.
	G. Use data collected to analyze and interpret trends in order to identify the positive and negative effects of a technology.
	H. Identify trends and monitor potential consequences of technological development.
	I. Interpret and evaluate the accuracy of the information obtained and determine if it is useful.
9-12	J. Collect information and evaluate its quality.
	K. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment.
	L. Use assessment techniques, such as trend analysis and experimentation, to make decisions about the future development of technology.
	M. Design forecasting techniques to evaluate the results of altering natural systems.

The Designed World

Standard 14. Students will develop an understanding of and be able to select and use medical technologies.

Grade Level	Benchmarks: *In order to select, use, and understand medical technologies, students should learn that:*
K-2	A. Vaccinations protect people from getting certain diseases.
	B. Medicine helps people who are sick to get better.
	C. There are many products designed specifically to help people take care of themselves.
3-5	D. Vaccines are designed to prevent diseases from developing and spreading; medicines are designed to relieve symptoms and stop diseases from developing.
	E. Technological advances have made it possible to create new devices, to repair or replace certain parts of the body, and to provide a means for mobility.

Standard 14, cont.

Grade Level		Benchmarks
	F.	Many tools and devices have been designed to help provide clues about health and to provide a safe environment.
6-8	G.	Advances and innovations in medical technologies are used to improve health care.
	H.	Sanitation processes used in the disposal of medical products help to protect people from harmful organisms and disease, and shape the ethics of medical safety.
	I.	The vaccines developed for use in immunization require specialized technologies to support environments in which a sufficient amount of vaccines is produced.
	J.	Genetic engineering involves modifying the structure of DNA to produce novel genetic make-ups.
9-12	K.	Medical technologies include prevention and rehabilitation, vaccines and pharmaceuticals, medical and surgical procedures, genetic engineering, and the systems within which health is protected and maintained.
	L.	Telemedicine reflects the convergence of technological advances in a number of fields, including medicine, telecommunications, virtual presence, computer engineering, informatics, artificial intelligence, robotics, materials science, and perceptual psychology.
	M.	The sciences of biochemistry and molecular biology have made it possible to manipulate the genetic information found in living creatures.

Standard 15. Students will develop an understanding of and be able to select and use agricultural and related biotechnologies.

Grade Level **Benchmarks:** *In order to select, use, and understand agricultural and related biotechnologies, students should learn that:*

Grade Level		Benchmarks
K-2	A.	The use of technologies in agriculture makes it possible for food to be available year round and to conserve resources.
	B.	There are many different tools necessary to control and make up the parts of an ecosystem.
3-5	C.	Artificial ecosystems are human-made environments that are designed to function as a unit and are comprised of humans, plants, and animals.
	D.	Most agricultural waste can be recycled.
	E.	Many processes used in agriculture require different procedures, products, or systems.
6-8	F.	Technological advances in agriculture directly affect the time and number of people required to produce food for a large population.
	G.	A wide range of specialized equipment and practices is used to improve the production of food, fiber, fuel, and other useful products and in the care of animals.
	H.	Biotechnology applies the principles of biology to create commercial products or processes.
	I.	Artificial ecosystems are human-made complexes that replicate some aspects of the natural environment.
	J.	The development of refrigeration, freezing, dehydration, preservation, and irradiation provide long-term storage of food and reduce the health risks caused by tainted food.
9-12	K.	Agriculture includes a combination of businesses that use a wide array of products and systems to produce, process, and distribute food, fiber, fuel, chemical, and other useful products.
	L.	Biotechnology has applications in such areas as agriculture, pharmaceuticals, food and beverages, medicine, energy, the environment, and genetic engineering.
	M.	Conservation is the process of controlling soil erosion, reducing sediment in waterways, conserving water, and improving water quality.
	N.	The engineering design and management of agricultural systems require knowledge of artificial ecosystems and the effects of technological development on flora and fauna.

Standard 16. Students will develop an understanding of and be able to select and use energy and power technologies.

Grade Level **Benchmarks:** *In order to select, use, and understand energy and power technologies, students should learn that:*

Grade Level		Benchmarks
K-2	A.	Energy comes in many forms.
	B.	Energy should not be wasted.
3-5	C.	Energy comes in different forms.
	D.	Tools, machines, products, and systems use energy in order to do work.
6-8	E.	Energy is the capacity to do work.
	F.	Energy can be used to do work, using many processes.
	G.	Power is the rate at which energy is converted from one form to another or transferred from one place to another, or the rate at which work is done.
	H.	Power systems are used to drive and provide propulsion to other technological products and systems.
	I.	Much of the energy used in our environment is not used efficiently.
9-12	J.	Energy cannot be created or destroyed; however, it can be converted from one form to another.

Standard 16, cont.

K. Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.
L. It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.
M. Energy resources can be renewable or nonrenewable.
N. Power systems must have a source of energy, a process, and loads.

Standard 17. Students will develop an understanding of and be able to select and use information and communication technologies.

Grade Level **Benchmarks:** *In order to select, use, and understand information and communication technologies, students should learn that:*

K-2
A. Information is data that has been organized.
B. Technology enables people to communicate by sending and receiving information over a distance.
C. People use symbols when they communicate by technology.

3-5
D. The processing of information through the use of technology can be used to help humans make decisions and solve problems.
E. Information can be acquired and sent through a variety of technological sources, including print and electronic media.
F. Communication technology is the transfer of messages among people and/or machines over distances through the use of technology.
G. Letters, characters, icons, and signs are symbols that represent ideas, quantities, elements, and operations.

6-8
H. Information and communication systems allow information to be transferred from human to human, human to machine, and machine to human.
I. Communication systems are made up of a source, encoder, transmitter, receiver, decoder, and destination.
J. The design of a message is influenced by such factors as the intended audience, medium, purpose, and nature of the message.
K. The use of symbols, measurements, and drawings promotes clear communication by providing a common language to express ideas.

9-12
L. Information and communication technologies include the inputs, processes, and outputs associated with sending and receiving information.
M. Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.
N. Information and communication systems can be used to inform, persuade, entertain, control, manage, and educate.
O. Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination.
P. There are many ways to communicate information, such as graphic and electronic means.
Q. Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.

Standard 18. Students will develop an understanding of and be able to select and use transportation technologies.

Grade Level **Benchmarks:** *In order to select, use, and understand transportation technologies, students should learn that:*

K-2
A. A transportation system has many parts that work together to help people travel.
B. Vehicles move people or goods from one place to another in water, air or space, and on land.
C. Transportation vehicles need to be cared for to prolong their use.

3-5
D. The use of transportation allows people and goods to be moved from place to place.
E. A transportation system may lose efficiency or fail if one part is missing or malfunctioning or if a subsystem is not working.

6-8
F. Transporting people and goods involves a combination of individuals and vehicles.
G. Transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively.
H. Governmental regulations often influence the design and operation of transportation systems.
I. Processes, such as receiving, holding, storing, loading, moving, unloading, delivering, evaluating, marketing, managing, communicating, and using conventions are necessary for the entire transportation system to operate efficiently.

9-12
J. Transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health and safety, and agriculture.

Standard 18, cont.

K. Intermodalism is the use of different modes of transportation, such as highways, railways, and waterways as part of an interconnected system that can move people and goods easily from one mode to another.

L. Transportation services and methods have led to a population that is regularly on the move.

M. The design of intelligent and non-intelligent transportation systems depends on many processes and innovative techniques.

Standard 19. Students will develop an understanding of and be able to select and use manufacturing technologies.

Grade Level	Benchmarks: *In order to select, use, and understand manufacturing technologies, students should learn that:*
K-2	A. Manufacturing systems produce products in quantity.
	B. Manufactured products are designed.
3-5	C. Processing systems convert natural materials into products.
	D. Manufacturing processes include designing products, gathering resources, and using tools to separate, form, and combine materials in order to produce products.
	E. Manufacturing enterprises exist because of a consumption of goods.
6-8	F. Manufacturing systems use mechanical processes that change the form of materials through the processes of separating, forming, combining, and conditioning.
	G. Manufactured goods may be classified as durable and non-durable.
	H. The manufacturing process includes the designing, development, making, and servicing of products and systems.
	I. Chemical technologies are used to modify or alter chemical substances.
	J. Materials must first be located before they can be extracted from the earth through such processes as harvesting, drilling, and mining.
	K. Marketing a product involves informing the public about it as well as assisting in selling and distributing it.
9-12	L. Servicing keeps products in good operating condition.
	M. Materials have different qualities and may be classified as natural, synthetic, or mixed.
	N. Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.
	O. Manufacturing systems may be classified into types, such as customized production, batch production, and continuous production.
	P. The interchangeability of parts increases the effectiveness of manufacturing processes.
	Q. Chemical technologies provide a means for humans to alter or modify materials and to produce chemical products.
	R. Marketing involves establishing a product's identity, conducting research on its potential, advertising it, distributing it, and selling it.

Standard 20. Students will develop an understanding of and be able to select and use construction technologies.

Grade Level	Benchmarks: *In order to select, use, and understand construction technologies, students should learn that:*
K-2	A. People live, work, and go to school in buildings, which are of different types: houses, apartments, office buildings, and schools.
	B. The type of structure determines how the parts are put together.
3-5	C. Modern communities are usually planned according to guidelines.
	D. Structures need to be maintained.
	E. Many systems are used in buildings.
6-8	F. The selection of designs for structures is based on factors such as building laws and codes, style, convenience, cost, climate, and function.
	G. Structures rest on a foundation.
	H. Some structures are temporary, while others are permanent.
	I. Buildings generally contain a variety of subsystems.
9-12	J. Infrastructure is the underlying base or basic framework of a system.
	K. Structures are constructed using a variety of processes and procedures.
	L. The design of structures includes a number of requirements.
	M. Structures require maintenance, alteration, or renovation periodically to improve them or to alter their intended use.
	N. Structures can include prefabricated materials.

Chapter 3 – Appendix C

Resources

Unit 1-5 Resources

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Wiens, A. E. (1997). Looking ahead: How will technology affect the future? *The Technology Teacher, 57*(3), 21-23.

Technological Systems Resources

Agricultural and Related Biotechnology

LaPorte, J. E., & Sanders, M. E. (1996). *The Technology, Science, Mathematics Connection Activities* [see the "Plant Plant" section for an example hydroponics activity]. New York: Glencoe McGraw-Hill.

Communication

Herrell, A. & Fowler, J. (1998). *Camcorder in the classroom: Using the video camera to enliven curriculum*. Upper Saddle River, NJ: Prentice Hall.

Maughan, G., & Prince Ball, K. (1999). Synergistic curriculum for the high performance workplace [teamwork and interoffice network communication]. *The Technology Teacher, 58*(7), 28-32.

North Carolina Department of Public Instruction. (1997). *Scientific and technical visualization I and II*. Raleigh, NC: Author.

Sanders, M. E. (1991). *Communication technology.* New York: Glencoe McGraw-Hill.

Construction

Kicklighter, C. (1995). *Architecture: Residential drawing and design.* Tinley Park, IL: Goodheart-Willcox.

Polette, D., & Landers, J. (1995). *Construction systems.* Tinley Park, IL: Goodheart-Willcox.

Wagner, W., & Smith, H. (1996). *Modern carpentry.* Tinley Park, IL: Goodheart-Willcox.

Energy

Smith, H. (1993). *Energy sources, applications, alternatives.* Tinley Park, IL: Goodheart-Willcox.

Manufacturing

Shackelford, R. (1993). Thermoforming plastics. *Ties Magazine, March-April,* 40-43.

Wright, J. R. (1999). Teaming: The key to world class manufacturing. *The Technology Teacher, 58*(5), 27-31.

Wright, R. T. (1990). *Manufacturing systems.* Tinley Park, IL: Goodheart-Willcox.

Medical and Related

Raines, A. (1999). Education for success [medical technology]. *Ties Magazine, November-December,* 14-17.

Transportation

Hadley, F. (1994). Resources in technology: Electric vehicle development. *The Technology Teacher, 54*(3), 15-24.

Johnson, S. R., & Farrar-Hunter, P. (1993). *Exploring transportation.* Tinley Park, IL: Goodheart-Willcox.

Jones, B. (1994). Building a solar powered vehicle. *The Technology Teacher, 54*(3), 25-29.

Missouri Alternative and Renewable Energy Technology Center. (1998). Solar BikeRayce. www.sunrayce.com/BikeRayce, [solar bicycle competition and teaching materials].

Northeast Sustainable Energy Association. (1999). www.nesea.org, [information on solar and alternative energy; NESEA is the sponsor of the American Tour de Sol, a solar vehicle competition].

Sepabfour, B. (1999). The great American moon buggy race. *Ties Magazine, October,* 4-6, 8-9.

General Technology-Related World Wide Web (WWW) Sites

Teachers should update this listing of WWW sites on a regular basis. URLs, or WWW site addresses, change frequently.

Brain, M. (1999). *How stuff works* [online]. Available: www.howstuffworks.com/index.htm
Description: Collection of animated explanations of how various technological processes work.

Center for Mathematics, Science, and Technology. (2000). *Integrated mathematics, science, and technology project (IMaST)* [online]. Available: www.ilstu.edu/depts/cemast/imastwelcome.html
Description: Provides general descriptions of IMaST and the modules developed as a result of the curriculum development project.

Council on Technology Teacher Education (CTTE) (2000). *Council on technology teacher education* [online]. Available: http://teched.edtl.vt.edu/CTTE/
Description: Provides a guide to professional and research activities in technology teacher education.

International Technology Education Association (ITEA). (2000). *Technology for all Americans* [online]. Available: www.iteawww.org/TAA/TAA.html
Description: Links with ITEA-CATTS material descriptions.

ITEA. (2000). *International technology education association* [online]. Available: www.iteawww.org/
Description: Links Publications/Curriculum Materials and Technology Education Resources. Order curriculum materials from the former. Browse K-12 sites from the latter.

ITEA. (2000). *TTTe: An electronic extension of the technology teacher* [online]. Available free to ITEA members: www.iteawww.org
Description: Collection of selected articles on technology education and technological studies.

ITEA and Council on Technology Teacher Education (CTTE). (2000). *Journal of technology education* [online]. Available: http://borg.lib.vt.edu/ejournals/JTE/jte.html
Description: Journal for research in technology education.

National Aeronautics and Space Administraion (NASA). (2000). *Education program* [online]. Available: http://education.nasa.gov/
Description: Links with a variety of educational programs, resources, and activities.

National Association of Industrial and Technical Teacher Educators (NAITTE). (2000). *National association of industrial and technical teacher educators* [online]. Available: www.orst.edu/dept/naitte/
Description: A guide to the professional activities of NAITTE.

NAITTE. (2000). *Journal of industrial teacher education* [online]. Available: http://borg.lib.vt.edu/ejournals/JITE/jite.html
Description: Research journal on technological-related education.

National Science Foundation. (2000). *Teacher resources* [online]. Available: www.ehr.nsf.gov/ehr/teachlinks/html/teachlinks.htm
Description: Collection of a variety of science teaching resources.

North Carolina Department of Public Instruction (NCDPI). (2000). *Teachers connect* [online]. Available: www.teachers-connect.net/
Description: Collection of a *wide* variety of general teaching resources.

NCDPI. (2000). *North Carolina info web for technology education* [online]. Available: www.dpi.state.nc.us/workforce_development/technology/index.html
Description: Provides an overview and guide to technology education in North Carolina. Includes links to technology education curriculum guides.

Omicron Tau Theta. (1999). *Journal of vocational-technical education* [online]. Available: http://scholar.lib.vt.edu/ejournals/JVTE/
Description: Research journal on technology-related and vocational education.

Technology Student Association (TSA). (2000). *Technology student association* [online]. Available: www.tsawww.org/
Description: A guide to teaching resources and activities related to the Technology Student Association.

Wheeling Jesuit University/NASA Classroom of the Future (COTF). (1998). *NASAs classroom of the future[tm]* [online]. Available: http://cotf.edu/
Description: Collection of the Classroom of the Future's own programs and activities and links with a variety of educational programs, resources, and activities.

COTFs *Bioblast* [online]. Available: www.cotf.edu/BioBLAST/main.html
Description: Collection of biotechnology-related activities.

COTFs *Exploring the environment* [online]. Available: www.cotf.edu/ete/main.html
Description: Collection of environment-related activities.

COTFs *Astronomy village* [online]. Available: www.cotf.edu/AV/main.html
Description: Collection of astronomy activities.

Other World Wide Web (WWW) Sites

Manufacturing

Society of Manufacturing Engineers. (2000). *Manufacturing is cool: Educational resources* [online]. Available: www.manufacturingiscool.com/cgi-bin/mfgcoolhtml.pl?/curricula.htm&

Soil Reclamation

Argonne National Laboratory, U.S. Department of Energy. (2000). *Energy and environment research highlights: Argonne sets standard for expedited site characterization* [online]. Available: www.anl.gov/OPA/Frontiers97/EE8.html

Argonne National Laboratory, U.S. Department of Energy. (2000). *Energy systems (ES) division* [online]. Available: www.es.anl.gov/htmls/remediation.html

Lindgren, E., Sandia National Laboratories. (2000) *Demonstration of electrokinetic remediation of chromium from unsaturated soil* [online]. Available: www.pnl.gov/WEBTECH/mwlid/electkin.html

Technology Assessment

Betts, P., Beyersdorfer, J., Nelson, S., Parrotte, D., Ristow, R., Vosburgh, A., & Zielinski, S. (1998). *Investigating Your Future* [online]. Available: www2.d21.k12.il.us/engaged_learning/FutureWeb/index.html

Videography

Videography Magazine. (2000). *Videography online: For video production professionals* [online]. Available: www.vidy.com/

Chapter 3 – Appendix D

Acceptable Evidence Glossary

Adequately – Sufficient for a specific requirement; also, barely sufficient or satisfactory.

Clearly – In a clear manner (easily heard, easily visible, free from obscurity or ambiguity, easily understood, unmistakable).

Correctly – 1. Conforming to an approved or conventional standard. 2. Conforming to or agreeing with fact, logic, or known truth. 3. Conforming to a set figure. 4. Conforming to the strict requirements of a specific ideology.

Create – 1. To make or bring into existence something new. 2. To invest with a new form, office, or rank; to produce or bring about through a course of action or behavior. 3. Cause, occasion. 4. To produce, through imaginative skill; to design.

Creatively – 1. The quality of being creative. 2. The ability to create.

Effectively – In an effective manner (producing a decided, decisive effect [result]).

Efficiently – Producing desired effects; productive without waste.

Insightfully – Exhibiting or characterized by insight (the power or act of seeing into a situation; the act or result of apprehending the inner nature of things or of seeing intuitively).

Introspectively – Behaving with introspection (a reflective looking inward; an examination of one's own thoughts and feelings).

Logically – Employing or behaving in accordance with logic (capable of reasoning or of using reason in an orderly, cogent fashion).

Marginally – Close to the lower limit of qualification, acceptability, or function; barely exceeding the minumum requirements.

Meaningfully – 1. Having meaning or purpose; full of meaning, significant.

Minimally – Relating to or being a minimum: the least possible; barely adequate.

Mostly – For the greatest part; mainly.

Randomly – 1. Lacking a definite plan, purpose, or pattern. 2. Being or relating to a set or to an element of a set each of whose elements has equal probability of occurrence.

Safely – Free from harm or risk; unhurt; secure from threat or danger, harm, or loss; affording safety or security from danger, risk, or difficulty.

Systematically – 1. Presented or formatted as a coherent body of ideas or principles. 2. Methodical in procedure or plan; marked by thoroughness and regularity.

Thoroughly – 1. Carried through to completion. 2. Marked by full detail; painstaking; complete in all respects.

Thoughtfully – 1. Absorbed in thought. 2. Characterized by careful, reasoned thinking. 3. Given to or chosen or made with heedful anticipation of the needs and wants of others.

Chapter 3 – Appendix E

Glossary – Engineering Design

Automatic Vehicle Identification (AVI) technology – AVI technology is used to collect real-time traffic information.

Agriculture – The process of raising crops and animals for food, fuel, and other useful products.

Alzheimer's disease – Alzheimer's disease (pronounced *AHLZ-hi-merz*) is one of several disorders that cause the gradual loss of brain cells. The disease was first described in 1906 by German physician Dr. Alois Alzheimer. Although the disease was once considered rare, research has shown that it is the leading cause of dementia.

Anthropometrics – The study of human body size and motion.

Arrhythmia – An irregular heart rhythm.

Atherosclerosis – A "hardening" of the arteries.

Assessment – A judgment about something based on an understanding of the situation.

Balloon angioplasty – Begins with the physician using a local anesthetic to numb a specific area of the patient's body, usually the upper thigh/groin area where the femoral artery is located. This is the artery into which a thin tube with an uninflated balloon at the tip (balloon-tipped catheter) will be inserted. The physician inserts the balloon-tipped catheter through the femoral artery all the way up to the heart. Once the balloon-tipped catheter is at the site of the blockage, the balloon at the tip of the catheter is inflated, pushing the plaque in the artery back against the wall of the artery. The balloon-tipped catheter is then removed or replaced with a stent (a wire mesh tube used to hold the artery open). The patient is then given time to recover. Most patients are free to go home after about 24 hours.

Benchmark – 1. A written statement that describes specific developmental components by various grade levels (K-2, 3-5, 6-8, and 9-12) that students should know or be able to do in order to achieve a standard. 2. A criteria by which something can be measured or judged.

Biodegradable – Made of substances that will decay relatively quickly as a result of the action of bacteria and break down into elements, such as carbon, that are recycled naturally.

Bioengineering – Engineering applied to biological and medical systems, such as biomechanics, biomaterials, and biosensors. Bioengineering also includes biomedical engineering as in the development of aids or replacements for defective or missing body organs.

Biotechnology – Practical use of biological processes: the use of biological processes or living microorganisms in industrial production. Early examples of biotechnology include the making of cheese, wine, and beer, while later developments include vaccine and insulin production.

Brainstorming – A method of shared problem solving in which all members of a group spontaneously and in an unrestrained discussion generate ideas.

British Thermal Unit (BTU) – One BTU or British thermal unit is an English standard unit of energy. One BTU is the amount of thermal energy necessary to raise the temperature of one pound of pure liquid water by one degree Fahrenheit at the temperature at which water has its greatest density (39 degrees Fahrenheit). This is equivalent to approximately 1055 joule (or 1055 watt-seconds).

Computer-Aided Design or Drafting (CAD) – Use of a computer and specialized software to generate, store, retrieve, plot, or print information and technical drawings to communicate ideas.

Computer Numerical Control (CNC) – Programmable systems that automatically control the manufacturing process.

Cardiac ischemia – The heart is not getting enough oxygen-rich blood.

Cardiac catheterization – A minimally invasive test that offers clear, accurate information about the heart, the coronary arteries located on the surface of the heart, and (depending on whether another test is done) the aorta.

Composite – A combination of two or more materials that are bonded together in an effort to provide better properties.

Composting – The controlled biological decomposition of organic matter, such as food and yard wastes, into humus, a soil-like material.

Concurrent engineering – A systematic approach to the integrated, simultaneous design of products and their related processes, including manufacturing and support.

Construction – The process of developing structures (such as buildings and bridges) on a site.

Content Standard – A written statement about what students should know and be able to do.

Controls – Mechanisms or activities that use information to cause change in systems.

Combustion – To reduce waste volume, local governments or private operators can implement a controlled burning process called combustion or incineration.

Conflict resolution – A wide range of processes that encourage nonviolent dispute resolution.

Coronary artery disease – A chronic disease in which there is a "hardening" of the arteries.

Cost/benefit analysis – Does the cost justify the product? A company would add up the benefits of a course of action, and subtract the costs associated with it.

Creative thinking – The ability or power used to produce original thoughts and ideas based upon reasoning and judgment.

Criterion – A desired specification (element or feature) of a product or system.

Curriculum – A plan for delivering content in the classroom.

Cybernetics – Study of automatic control systems: the science or study of communication in organisms, organic processes, and mechanical or electronic systems.

Data – Factual information: information, often in the form of facts or figures obtained from experiments or surveys, used as a basis for making calculations or drawing conclusions.

Delta T – The change in temperature. For example if outside it is -20 degrees Fahrenheit and inside it is 70 degrees Fahrenheit, the delta T is 90 degrees Fahrenheit.

Design – An iterative decision-making process in which plans are produced and implemented to devise an effective solution to problems or to meet identified needs and wants.

Diastolic – The number that represents the pressure when a person's heart is resting between beats.

Discovery – An insight into the existence of something previously unknown. The act of finding out something new.

Drawing – A work produced by representing an object or outlining a figure, plan, or sketch by means of lines. A drawing is used to communicate ideas and provide direction for the production of a design.

EKG – An electrocardiogram (EKG or ECG) is a recording of the heart's electrical activity as a graph or series of wave lines on a moving strip of paper.

Economy – The production and consumption of goods and services of a community regarded as a whole.

Energy – The ability to do work. Energy is one of the basic resources used by a technological system.

Engineering – The application of mathematics and the sciences in a practical application.

Engineering design – The systematic and creative application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.

Engineering ethics – (1) The study of moral issues and decisions confronting individuals and organizations involved in engineering and (2) the study of related questions about moral conduct, character, ideals, and relationships of people and organizations involved in technological development.

Environment – The circumstances or conditions that surround one; surroundings.

Ergonomics – The study of workplace equipment design or how to arrange and design devices, machines, or workspace so that people and things interact safely and most efficiently. Also called human factors analysis or human factors engineering.

Ethical – Conforming to an established set of principles or accepted professional standards of conduct.

Feedback – Readings, information, or results from the system process (for example, a speedometer in a vehicle).

Finite Element Analysis (FEA) – Finite element analysis software products can solve all types of linear and nonlinear stress, dynamics, composite, and thermal engineering analysis problems.

Flow chart – Diagram showing a sequence of actions: a diagram that represents the sequence of operations in a process.

Global Positioning System (GPS) – GPS is funded by and controlled by the U.S. Department of Defense (DOD). While there are many thousands of civil users of GPS worldwide, the system was designed for and is operated by the U.S. military. GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity, and time. Four GPS satellite signals are used to compute positions in three dimensions and the time offset in the receiver clock.

Green Map – The Green Map System is a globally connected, locally adaptable eco-cultural program for community sustainability. Green Maps (both printed and online) utilize Green Map Icons to chart the sites of environmental significance around the world.

Group dynamics – Behavior of individuals within groups: the interpersonal processes, conscious and unconscious, that take place in the course of interactions among a group of people (*takes a singular verb*).

High Occupancy Vehicle lanes – HOV lanes are built primarily for buses; the HOV lanes also promote ride sharing through vanpools and carpools.

Human Factors Engineering – (Ergonomics.) The study of the human body, its size and motions, as it is related to the design of a product or a system.

Industrial Revolution – The social and economic changes in Great Britain, Europe, and the United States that began in the second half of the eighteenth century and involved widespread adoption of industrial methods of production. The specialization of tasks, the concentration of capital, and the centralization of work forces were important aspects of these changes, which first affected Great Britain.

Informational Technology – Processes associated with generating, storing, retrieving, transferring, and modifying information and data.

Innovation – The act of introducing something new. Also an improvement of an existing product, system, or method.

Input – Supply of information to a system for processing (for example, pressing on an accelerator in a vehicle).

Integrated Product Development (IPD) – A philosophy that meticulously teams functional disciplines to integrate and simultaneously meshes all prescribed processes to produce an effective and efficient product that satisfies the customer's needs.

Intermodal Transportation (Intermodalism) – Using more than one form of transportation to move goods.

Invention – A new product, system, or process that has never existed before, created by study and experimentation.

KEVLAR® – A material that is five times stronger than steel on an equal weight basis, yet, at the same time, is lightweight, flexible, and comfortable.

Landfill – An system of trash and garbage disposal in which the waste is buried between layers of earth to build up low-lying land. Although source reduction, reuse, recycling, and composting can divert large portions of municipal solid waste (MSW) from disposal, some waste still must be placed in landfills. Modern landfills are well-engineered facilities that are located, designed, operated, monitored, closed, cared for after closure, cleaned up when necessary, and financed to ensure compliance with federal regulations.

Manufacturing – A set of processes associated with making a product from raw materials in a plant or factory.

Measurement – The process of using dimensions, quantity, or capacity by comparison with a standard in order to mark off, apportion, lay out, or establish dimensions.

Medical Technology – Of or relating to the study of medicine through the use of and advances of technology, such as medical instruments and apparatus, imaging systems in medicine, and mammography. Related terms: bio-medical engineering and medical innovations.

Model – A visual, mathematical, or three-dimensional representation in detail of an object or design, often smaller than the original. A model is often used to test ideas, make changes to a design, and to learn more about what would happen to a similar, real object.

MP3 files – MP3 files are actually MPEG files. The MPEG format was originally developed for video by the Moving Pictures Experts Group. We can say that MP3 files are the sound part of the MPEG video format. MP3 is one of the most popular sound formats for music recording. The MP3 encoding system combines good compression (small files) with high quality. Expect all your future software systems to support it.

Multimeter – An instrument that reads and measures the values of several different electrical parameters such as current, voltage, and resistance.

Municipal Solid Waste – More commonly known as trash or garbage—consists of everyday items such as product packaging, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries.

Napster – Napster was a protocol for sharing files between users. With Napster, the files stayed on the client machine, never passing through the server. The server provided the ability to search for particular files and initiate a direct transfer between the clients.

Noninvasive – A test or procedure that can be conducted without any tools entering the patient's body.

Nuclear stress test – In addition to the procedures that are performed as part of a standard stress test, a patient scheduled for a nuclear stress test is injected with a very small, harmless amount of a radioactive (*radionuclide*) substance, such as thallium. Once in the patient's body, this substance emits rays that can be picked up by a special (*gamma*) camera. The rays allow the camera to produce clear pictures of heart tissue on a video monitor. These pictures show contrasts between light and dark spots, which can indicate areas of damage or reduced blood flow that are present before, during, and after exertion.

Optimization – The process involved in designing and making products and systems to be as effective as possible.

Orthographic projection – That projection that is made by drawing lines from every point to be projected, perpendicular to the plane of projection. Such a projection of the sphere represents its circles as seen in perspective by an eye supposed to be placed at an infinite distance, the plane of projection passing through the center of the sphere perpendicularly to the line of sight.

Output – The result of the process stage of the systems loop (for example, the vehicle speeds up after it processes the input from the accelerator).

Patent – A document issued from the government granting the exclusive right to produce or sell an invention for a certain time.

Peer evaluation – A way to evaluate members within a peer group by the group, according to their participation on a project.

Pharmaceuticals – Natural or artificial substances that are given to treat, prevent, or diagnose a disease or to lessen pain.

Photochemistry – Study of the chemical effects of light: a branch of chemistry that studies the effect of radiation, especially of visible and ultraviolet light, on chemical reactions and of the emission of radiation by chemical reactions.

Photovoltaic – Capable of producing a voltage when exposed to radiant energy, especially light.

Pictogram – Instructions in "cartoon" format so that language is not a problem for people.

Polymer – Any of numerous natural and synthetic compounds of usually high molecular weight consisting of up to millions of repeated linked units, each a relatively light and simple molecule.

Poly Vinyl Chloride (PVC) – A polymer (plastic) typically used in household plumbing and other applications.

Problem solving – A decision-making process that begins with identification of a problem and results in one or more effective solutions.

Process – A series of actions, changes, or functions bringing about a result. Examples are the process of making steel, the process of converting electrical signals to audible sounds, etc.

Product lifecycle – Stages a product goes through from concept and use to eventual withdrawal from the marketplace. Product life cycle stages include research and development, introduction, market development, exploitation, maturation, saturation, and finally decline.

Professional Engineer (PE) – Only a licensed engineer may prepare, sign and seal, and submit engineering plans and drawings to a public authority for approval, or seal engineering work for public and private clients.

Prototype – A full-scale, working model used to test a design.

Quality control – A system for ensuring the maintenance of proper standards in manufactured goods, especially by periodic random inspection of the product.

R and D – Research and Development. The process used when developing a new or refined product or system.

R-Value – The resistance level of a material. This number can be associated with building materials lists or can be derived from an experiment that can be done to determine the R-value of a material.

Recycling – To reclaim or reuse old materials in order to make new products. Recycling turns materials that would otherwise become waste into valuable resources and generates a host of environmental, financial, and social benefits.

Requirement – Desired element or limitation of a design.

Renaissance – The transitional movement in Europe between medieval and modern times beginning in the fourteenth century in Italy, lasting into the seventeenth century, and marked by a humanistic revival of classical influence expressed in a flowering of the arts and literature and the beginnings of modern science.

Request For Proposal (RFP) – An RFP in its most formal sense is a specification of requirements that is sent out to suppliers who reply with proposals. Although common with large companies, the idea can be usefully applied at varying levels of sophistication to small and medium organizations as well. Used properly, it is a tool that supports and protects the buyer.

Resource – Something that lies ready for use or can be drawn upon for aid.

Risk/benefit analysis – Does the risk of building the product outweigh the negative societal impact? *Risk = probability of event x cost of event.*

Rubric – An established rule, tradition, or custom.

Social – Relating to human society and how it is organized.

Source Reduction – Often called waste prevention, means consuming and throwing away less.

Standardization – The act of checking or adjusting by comparison with a standard.

Sustainable development – Improving the quality of human life while living within the carrying capacity of supporting ecosystems.

Systems – A functionally related group of elements. A group of interrelated parts that function together to accomplish a goal.

Systolic – The number that represents the pressure while a person's heart is beating.

Teamwork – A cooperative effort by the members of a group or team to achieve a common goal.

Technological literacy – The ability to understand, use, manage, and assess technology.

Technology – Human innovation in action that involves the generation of knowledge and processes to develop systems that solve problems and extend capabilities.

Thumbnail sketching – Small drawings/sketches used during brainstorming. These are not to scale and usually small, hence the name thumbnail.

Tolerances – Allowed amount of variation from the standard or from exact conformity to the specified dimensions, weight, etc., as in various mechanical operations.

Trade-off – An exchange of one thing in return for another; especially relinquishment of one benefit or advantage for another regarded as more desirable.

Troubleshooting – Finding and eliminating problems: the act or process of identifying and eliminating problems, difficulties, or faults, especially in electronic or computer equipment.

U-Factor – The combined thermal conductivity of materials (1/R Value).

Ultrasound – The ultrasound machine sends out high-frequency sound waves that bounce off body structures to create a picture. Pregnancy ultrasound is a method of imaging the fetus and the female pelvic organs during pregnancy.

Ylem – Dry, white, "Minute" brand medium grain rice, representing the material to be recycled.

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